

QAPP

FOR

**CARBON OFFSET FORESTRY: FORECASTING ECOSYSTEM EFFECTS
(COFFEE)**

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Principal Investigators: Christian Andersen, Peter Beedlow, Donald Ebert, Mark Johnson, Jonathan Maynard, Bob McKane, Donald Phillips, Nathan Schumaker

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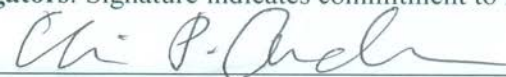
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A. PROJECT MANAGEMENT

A1 Project/Task Organization

The Carbon Offset Forestry: Forecasting Ecosystem Effects (COFFEE) project is organized into six tasks (Figure 1). Task 1 (*Policy and Environmental Drivers*) will provide “Carbon Offset Forestry” (COF) scenarios for the various land ownership categories of Willamette River Basin (WRB) coniferous forest lands, and downscaled global climate change (GCC) scenarios for those lands. Task 2 (*COF Scoring Metrics and Scaling to Landscapes*) will develop (1) metrics to score COF that are amenable to assessing affects of GCC scenarios, and trade-offs among COF practices and changes in ecosystem services (ESs), and (2) methods to extrapolate (scale) the outcomes as spatial representations. Finally, four tasks, Tasks 3-6, [*Effects of COF and GCC on ... (each of the four ESs)*] will produce information for each ES on its responses to COF and GCC scenarios.

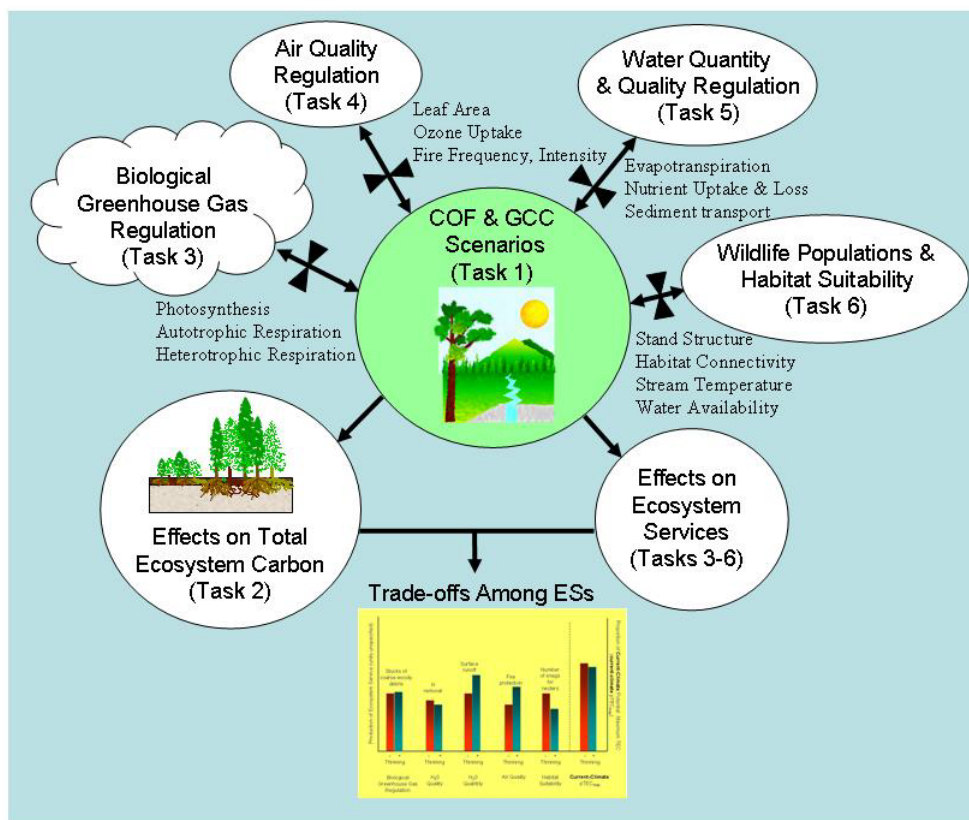


Figure 1. Task structure of COFFEE. The metric for scoring COF practices will be alteration in attaining pTEC_{max} (Task 2). One policy driver (COF, Task 1) singly, and together with the effects of a changing climate (Task 1), will be assessed for consequent quantified changes in productions of four ESs (Tasks 3-6). Linking changes in each ES, via ERFs, to ecosystem processes and state variables (indicated at the bowties) and to potential maximum Total Ecosystem Carbon (pTEC_{max}) will relate COF to each ES. Determining trade-offs among COF and the four ESs will yield assessment of effects of COF practices and GCC scenarios on quantified delivery of ESs.

There will be other activities (i.e., Interactions with other Projects, Interactions with Clients and Stakeholders, Integration and Inference, and Field Sites). While these five activities will contribute

directly to the successful outcome of COFFEE, only the last activity (Field Sites) will require SOPs and these will be integrated into the project activities related to collecting primary data (see ***Role of Appendices and related SOPs, and Relationships to the QAPP***, below in this section). The first four activities above are intended to assist in structuring COFFEE in the general sense, and the activities within each of them are not necessarily specific to any individual COFFEE task. Rather, all relevant QAPP elements related to these activities will be addressed in the appropriate Appendices.

COFFEE builds on the approach of the *Willamette Alternative Futures Project* (WAFP) and will utilize the new Willamette Ecosystem Services Project (WESP) *Envision* decision support platform (DSP) for evaluating policy options. *Envision* DSP (henceforth called *Envision*) is an alternative futures scenario toolset designed to develop suites of future scenarios reflecting possible decisions and consequent effects on landscape change and provisioning of ESs. Results of COFFEE activities will be used (1) in assessments and models specific to COFFEE, and (2) as inputs to *Envision* which then will produce suites of future outcomes concerning future GCC scenarios and possible decisions to implement COF, and the provisioning of the ESs. Collectively, COFFEE and WESP will provide suites of outcomes of alternative futures relevant to the interests of the two EPA national programs; Ecosystem Services Research Program (ESRP) and Global Change Research Program (GCRP).

COFFEE, and its various components, will be managed and executed by a core team of researchers located at the Western Ecology Division (WED), Corvallis, and the Environmental Sciences Division (ESD), Las Vegas (Table 1). Collaborative work (e. g., experimental work on public and/or private lands) will occur both within and outside of EPA. In particular, we will maintain linkages with related efforts, particularly with the staff of WESP with the goal of developing products and approaches relevant to both efforts.

Table 1. Project management and the project in which primary responsibility of the researcher resides. Note: (W) signifies primary responsibilities reside in WESP, and he/she represents the interests of WESP to COFFEE as a consultant to COFFEE; (C/W) denotes responsibilities divided between the two projects; D. Phillips' primary responsibility is on COFFEE and he represents COFFEE to WESP as a consultant to WESP.

Activity	Principal	Participant	Participant	Participant	Participant	Participant	Participant
Tasks							
Task 1 Policy and Environmental Drivers							
	D. Phillips	P. Beedlow	E.H. Lee				
Task 2 – COF Scoring Metrics and Scaling to Landscapes							
	M. Johnson	P. Rygiewicz	B. McKane (W)	D. Ebert	P. Beedlow	J. Maynard	M. Nash
		C. Burdick (C/W)	E.H. Lee	R. Waschmann			
Task 3 – Effects of COF and GCC on Biological Greenhouse Gas Regulation (BGHGR)							
	C. Andersen	B. McKane (W)	J. Maynard	R. Waschmann			
Task 4 – Effects of COF and GCC on Air Quality Regulation							
	D. Phillips	C. Andersen	C. Burdick (C/W)				
Task 5 – Effects of COF and GCC on Water Quantity and Quality Regulation							
	B. McKane (W)	J. Maynard					

Task 6 – Effects of COF and GCC on Wildlife Populations and Habitat Suitability

P. Rygiewicz	N. Schumaker (W)	B. McKane (W)	D. Phillips
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Interaction with other Projects

WESP & Envision

D. Phillips	B. McKane (W)	D. Ebert	C. Burdick (C/W)
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Non-Navigable Streams and Wetlands (NSW) Project: Hydrologic Landscape Regions

B. McKane (W)	D. Ebert	M. Johnson	J. Maynard
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Interaction with Clients and Stakeholders

P. Beedlow	D. Phillips	P. Rygiewicz
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Integration and Inference

P. Rygiewicz	All Project PIs
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Field Sites

P. Rygiewicz	P. Beedlow	B. McKane (W)	C. Andersen	M. Johnson	J. Maynard	R. Waschmann
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Quality Assurance

P. Rygiewicz	All Project PIs
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The Project Leader will coordinate project activities and is responsible for producing the research.

Objectives of Project Leader Responsibilities

- Establish expectations and interactions to maximize resources and ensure relevance of work and outcomes.
- Allocate budget among tasks in a responsible manner.
- Ensure that PIs and Task Leaders develop active, relevant, and appropriate collaborations inside and outside WED, ESD and ORD.
- Ensure that the project meets WED and ESD QA requirements.
- Ensure periodic peer review of the research project.

Approach of Project Leader to Accomplish the Work of the Project

The Project Leader will implement research through the Task Leaders (Table 1):

- | | |
|--------|---|
| Task 1 | Policy and Environmental Drivers – Don Phillips |
| Task 2 | COF Scoring Metrics and Scaling to Landscapes – Mark Johnson |
| Task 3 | Effects of COF and GCC on Biological Greenhouse Gas Regulation (BGHGR) – Chris Andersen |
| Task 4 | Effects of COF and GCC on Air Quality Regulation – Don Phillips |
| Task 5 | Effects of COF and GCC on Water Quantity and Quality Regulation – Bob McKane |
| Task 6 | Effects of COF and GCC on Wildlife Populations and Habitat Suitability – Paul Rygiewicz |

Task Leaders will recommend allocating resources, coordinating research with PIs and support staff, and will meet QA requirements of their tasks. Research activities within tasks will be reviewed for project alignment and budgetary requirements jointly by the Task Leaders and the Project Leader, who then recommends staffing and funding allocations to the Ecological Effects Branch Chief.

Project Leader Actions and Relationships to Deliverables

Project Leader responsibilities include:

- Empower and engage EPA research scientists to promote innovative research.
- Recommend allocation of resources that result in EPA-relevant products.
- Ensure appropriate outreach is done with collaborators, stakeholders and clients.
- Work with Task Leaders, PIs, other project staff and the QA Officers at WED and ESD QA to establish a QA Project Plan (QAPP).
- Oversee Task Leaders that they ensure task SOPs are written and kept current.
- Brief EPA management on outcomes and progress.
- Organize and conduct project peer and management reviews.

Role of Appendices and related SOPs, and Relationships to the QAPP

The breadth of activities to be done on COFFEE are diverse scientifically, and it will be necessary for COFFEE participants to interact with a great variety of individuals from many institutions to accomplish the goals of the project, including personnel of the WED on-site contractors, other EPA laboratories, EPA Regional Offices, and other federal entities (e.g., NSF, USFS, etc.), as well as expert hires funded via EPA research programs [e.g., the Ecosystem Services Research Program (ESRP) and the Global Change Research Program (GCRP)]. Some COFFEE goals will be achieved by COFFEE participants talking with various stakeholder groups, keeping current on pending legislation and about developments in various regional carbon markets. Other times, COFFEE participants will rely on the outputs of other EPA efforts, e.g., downscaled GCC scenarios which will be done by the GCRP via the National Center for Environmental Assessment (NCEA) and the National Exposure Research Laboratory (NERL). Meeting other goals may involve mining of published data, use of published models, or collection of original data. These various activities have been organized scientifically into several Tasks (Table 1, above) in the WED COFFEE Research and Implementation Plan. However, given the diversity of types of activities that may be found in each Task, in sub-tasks, and across the project at-large (e.g., developing using COF and GCC scenarios, collecting primary data, using models, etc.) this QAPP, for QA/QC purposes, is organized along four overarching categories of activities into which all of the activities to be done on the project can be assigned. For the purposes of describing the QA/QC elements required in this QAPP, the four overarching categories will be presented as four Appendices amended to this QAPP:

- Appendix 1. Scenarios Development
- Appendix 2. Spatial Analysis
- Appendix 3. Collecting Primary Data
- Appendix 4. Modeling

The progress and success of the COFFEE project is highly integrated with the progress and success of WESP, and both projects are subject to modifications due to, for example, legislative action, development of regional climate initiatives and carbon markets, and evolution of positions and management practices of stakeholders and land managers to develop more specific COF management

practices to thereby benefit from the carbon markets. Consequently, the COFFEE project very likely will need to adjust its activities to address the outcomes of these developments. Therefore, the four Appendices of this QAPP are to be viewed as “snapshots” of current activities reflecting our current thinking; current being indicated by the date on the individual Appendix. Appendices will be reviewed by the Project Leader and project participants periodically (e.g., semi-annually or annually, depending on the extent of external and internal (to EPA) developments will have occurred and that will have impinged on project activities. Each Appendix will be revised as needed, and revised Appendices will be submitted to the WED QA program for review and re-authorization.

A2 Problem Definition/Background

Growing concern that increasing atmospheric greenhouse gas (GHG) concentrations, principally CO₂, will lead to global climate change and widespread impacts has prompted U.S. legislators to consider a national policy to limit GHG buildup by instituting “cap and trade” programs for emitters. Such programs may allow a portion of the emissions cap to be “offset” by CO₂ sequestration achieved elsewhere (i.e., by someone other than the emitters). Options for offsets include geologic and terrestrial ecosystem sequestration; the greatest potential for the latter may be by increasing net primary productivity and carbon (C) sequestration in forests using COF practices. In general, management practices of COF will involve variations in harvesting (e.g., clear cutting versus thinning versus variations of partial removal protocols, harvest interval, and slash management), thinning (timing and intensity), pruning, fertilization [e.g., amount, form, frequency, and timing (i.e., with respect to season and stand age)], and changes in tree species. Forest C offsets are included in most proposed national and international strategies. The U.S. does not have a national mandatory cap and trade program with offsets but it may become a reality. Should it arise, assessing the environmental consequences will be vital. EPA was charged with preparing for this outcome by evaluating the environmental effects [(i.e., on ESs) of COF.

ESs are benefits that humans obtain from ecosystem processes. This definition has become an organizing concept for ORD for assessing environmental effects and is the focus of a major research program. It is likely that these COF practices and changes in climate will affect essentially all ecological processes in varying degrees (e.g., hydrological, biogeochemical, population dynamics, fire frequency and intensity, etc.), thereby altering the delivery of many ESs. For example, reforestation, afforestation or fertilizing areas to sequester C could change biogenic emissions, particulate matter release due to wildfires, water quality, and peak and low flows of water, etc. To the extent that mitigation rules likely will include forest offsets, the Agency needs to evaluate the environmental effects of COF practices, particularly with regard to water quality and other ESs.

An overarching goal of COFFEE is to assess potential environmental effects of COF at a scale that is large enough to encompass interactions between public policy, economic drivers and environmental issues. Western Oregon, specifically the WRB, provides such a setting. It is 1) an important region for forest resources, 2) the location of a major river, 3) a varied agricultural region, 4) where most of the state’s population resides, and 5) the locale for one of the “place-based” studies of ORD’s research program quantifying trade-offs among bundles of ESs and among social outcomes, resulting from implementing decisions on policy options while considering effects of changing environmental and other drivers.

COFFEE will evaluate implementing various COF practices by using the amount of total ecosystem C (TEC) sequestered in forests as the integrative response metric. These evaluations will be done for current-climate and future-climate scenarios and will relate changes in the COF scoring metric with trade-offs among four ESs: **Biological Greenhouse Gas Regulation (BGHGR), Air Quality Regulation, Water Quality and Quantity Regulation, and Wildlife Populations and Habitat Suitability**. Several criteria were used to identify the ESs to be investigated in COFFEE including EPA's regulatory authorities, EPA client needs, and stakeholder (i.e., outside EPA) interests, etc. Important clients are the EPA program offices (e.g., Office of Water, Office of Air, and Office of Science Policy) as well as EPA regional offices. Stakeholders include state departments responsible for implementing EPA regulations; the various federal, state, local government, and private forest landowners and land managers; and Non-governmental Organizations (NGOs).

Our focus is on determining quantified changes in provisioning of ESs related to implementing COF policies, in light of future GCC scenarios. By “quantified” we mean the estimated physical amounts of materials (e.g., kg/ha of C, nitrogen, water, etc.) produced or provided by different ESs within a specified area. Seven major research questions will be addressed:

1. What are the relevant forest ecosystem C and N processes and pools (aboveground, belowground, and per various quality fractions) that may be used to assess the potential of a parcel of coniferous forest land to sequester total ecosystem carbon (i.e., $pTEC_{max}$)?
2. What are the relationships between $pTEC_{max}$ and its various component pools, and consequent changes in ESs?
3. What is the potential for a parcel of coniferous forest land, under current climate conditions, to sequester C (i.e., what is **current-climate** $pTEC_{max}$)?
4. How will future scenarios of atmospheric CO₂ concentrations and GCC alter **current-climate** $pTEC_{max}$ (i.e., what is **future-climate** $pTEC_{max}$)?
5. How will COF practices alter the trajectory of a parcel of coniferous forested land to attain its **current-climate** and **future-climate** $pTEC_{max}$?
6. For alternative COF policy scenarios (e.g., business as usual, maximized C sequestration, and maximized extraction of forest products), what are the trade-offs among the ESs of interest to COFFEE?
7. How can our projected outcomes for trade-offs among ESs due to COF practices and future changes in atmospheric CO₂ and climate change scenarios be scaled/extrapolated to the entire WRB?

We will not design COF practices, develop practices to sequester C biologically, or estimate or compare efficacies of COF practices, all of which are activities of other federal agencies.

COFFEE is an example of ORD's emerging Integrated Transdisciplinary Research (ITR) approach. COFFEE PIs are affiliated with two EPA national labs [National Health and Environmental Effects Research Laboratory (NHEERL) and NERL]. We will be addressing needs of two EPA national programs [GCRP, and Ecosystem Services Research Program (ESRP)]. Determining effects of implementing a COF policy will require collaborating with other EPA projects, efforts and laboratories including: the WED's WESP, WED's *Non-Navigable Streams and Wetlands* (NSW) Project, the ESRP Nitrogen Theme, the ESRP National Atlas of Ecosystem Services, and the National Center for Environmental Assessment (NCEA) – Climate Change.

COFFEE is organized into six tasks. One task (*Policy and Environmental Drivers*) will provide COF scenarios for the various land ownership categories of WRB coniferous forest lands, and downscaled GCC scenarios for those lands. Another task (*COF Scoring Metrics and Scaling to Landscapes*) will develop (1) metrics to score COF that are amenable to assessing effects of GCC scenarios, and trade-offs among COF practices and quantified changes in productions of ESs, and (2) methods to extrapolate (scale) these outcomes as spatial representations. Finally, four tasks [*Effects of COF and GCC on ... (each of the four ESs)*] will produce information for each ES on its responses to COF and GCC scenarios.

EPA clients (e.g., Program Offices; Regions; and the Offices of Science Policy, Water, and Air) frequently base their decisions on marginal change to one attribute of the environment due to a stressor/driver or multiple stressors/drivers. Ideally, decisions would be made while assessing marginal changes in numerous attributes of the environment as multiple stressors are imposed. However, decision tools that accommodate multiple stressors and multiple environmental endpoints are not available to assess the merits of various policy options. COFFEE builds on the approach taken by the WAFP and will utilize the new *Envision* tool for evaluating policy options. *Envision* is an alternative futures scenario toolset designed to develop suites of future scenarios reflecting possible decisions and consequent effects on landscape change and quantified changes in the provisioning of ESs. A major output of the COFFEE-WESP/*Envision* collaboration will be a proof-of-concept application of this type of decision tool. Through collaborating, COFFEE and WESP will demonstrate the usefulness of *Envision* that can provide suites of outcomes of alternative futures relevant to the interests of the two EPA national programs, a number of EPA client offices and regions, and external stakeholders.

A3 Task Descriptions

Task 1 – Policy and Environmental Drivers

COFFEE will evaluate potential effects of COF on ESs, and how those effects may be modified by climate change. Task 1 defines the policy and climate change scenarios needed to address how these factors will affect future land use. This task thus sets the stage for addressing major science questions 4-6:

4. How will future scenarios of atmospheric CO₂ concentrations and GCC alter **current-climate** pTEC_{max} (i.e., what is **future-climate** pTEC_{max})?
5. How will COF practices alter the trajectory of a parcel of coniferous forested land to attain its **current-climate** and **future-climate** pTEC_{max}?
6. For alternative COF policy scenarios (e.g., business as usual, maximized C sequestration, and maximized extraction of forest products), what are the trade-offs among the ESs of interest to COFFEE?

COF Scenarios

As public policy continues to evolve regarding using forests to mitigate increasing concentrations of atmospheric CO₂, it is likely that COF will be implemented differently in private, federal, and local government and state forest sectors. Private (including corporate) forest landowners may alter their

usual forest management practices (“baseline”) to establish that their forests are sequestering CO₂ to increased extents (“additionality”) that will continue over a long-term (“permanence”), in order to qualify to sell forest C offsets in an open market (see California forest protocols for definitions <http://www.climateregistry.org/tools/protocols/industry-specific-protocols/forests.html>). The extent to which they are enticed to do so will likely depend on economic drivers, such as the price of offset C (\$/ton CO₂) versus returns for other management practices (e.g., timber harvest revenue from continued “baseline” practices). Similar economic drivers could lead owners of non-forest land to convert their holdings to forest (afforestation) to market C offsets if that were to provide a greater economic return than alternative land uses. Public forest lands (state, federal) may not participate directly in a C offset market, although some in Congress that are seeking this opportunity for federal forests (Preusch 2009). There is also interest in developing carbon credits for some state forests (Rosemary Mannix, Oregon Dept. of Forestry, *personal commun.*). However, even if public forests do not provide marketable C offsets as private forests might, increasing awareness to mitigate increasing atmospheric CO₂ concentrations may lead to changes in public forest management policy that give higher priority to this goal.

This portion of Task 1 involves developing policy scenarios for land use and land management decisions affecting provision of forest C offsets; these scenarios can then be used in other COFFEE tasks for assessing their impacts on ESs. As an initial test phase, we are examining scenarios developed in WAFP (Baker et al. 2004; Hulse et al. 2002) as analogs of some aspects of COF scenarios and the resulting differences in various ESs between those scenarios. These scenarios represent land use and management along several alternative development trajectories over 1990-2050. The Plan Trend scenario is considered as the baseline, and the Conservation scenario as adopting various COF practices. These practices vary among ownership categories but include: increased reserves with limited thinning, establishment of conservation areas for endangered species, increased riparian zone buffers, increased rotation length, decreased harvest patch size, and other aspects consistent with the *Northwest Forest Plan* (U.S. Department of Agriculture - Forest Service and U.S. Department of Interior - Bureau of Land Management 1994). We are summarizing analyses of ESs and related indicators for these scenarios and examining differences among them. Because of the multi-faceted nature of these scenarios, all changes in ESs cannot be attributed unequivocally to implementing COF practices, but the scenarios serve as reasonable analogs of baseline and COF management portfolios. Availability of extensive work to develop scenarios and assess ecological conditions from WAFP provided “low hanging fruit” for a first look at environmental effects of COF. A journal manuscript reporting results of the analyses from this initial test phase will be an early product of COFFEE.

Moving beyond this initial test phase using COF analog scenarios, further work in Task 1 will involve developing more explicit policy scenarios for land use and land management decisions affecting provisioning of forest C offsets. These policies will be encoded using the Policy Editor in *Envision* (Bolte 2009). WESP will use *Envision* to create land use scenarios as a result of various policy drivers (of which COFFEE’s COF policies are one set) and run linked simulation models on those land use scenarios. COFFEE will synthesize the results of these simulations to determine effects of COF and climate change on ESs (see Tasks 3-6).

Envision divides the landscape into Integrated Decision Units (IDUs) that represent units on which land use and management decisions are made (Bolte 2009; Bolte et al. 2007). It contains spatial

representations of land cover, biophysical attributes (e.g., elevation, aspect, soil class, soil N, TEC, etc.), and other attributes (e.g., zoning, etc.) for each of these IDUs. Policy definitions specify where policies are applicable (e.g., federal forests > 80 years of age), when policies are in effect, and what the outcomes are and with what probability. For example, one could specify that federal forests > 80 years of age have a 10% probability of being clear-cut harvested in the current year and a 90% probability of remaining uncut. IDUs for which that policy is selected (e.g., clear-cut harvested) will have their site attributes modified accordingly (e.g., reclassified as 0-20 year old forest instead of 80-120 year old forest) and resulting landscape maps will reflect these changes.

Defining scenarios to reflect COF policies for private and public forests is a critical early activity for COFFEE in using *Envision* to assess changes in landscapes and ESs in response to COF. While this policy arena is evolving, as a first step we will consult with a small group of experts to define a preliminary set of COF scenarios that reflect shifting priorities toward forest conservation and increased TEC for public forests, and economic drivers for marketable C offsets for private forests and afforestation programs. Initially, we will draw on the expertise of PNW Region USDA Forest Service (USFS), and OSU scientists collaborating in our ongoing EPA-USFS Interagency Agreement *Evaluating western Oregon land use and forest management responses to potential CO₂ sequestration policies*. This Interagency Agreement started in 2009 for “development of models of land use and forest land management decisions of private landowners in western Oregon, simulating land use and forest management responses to CO₂ sequestration policies and programs”.

Specific IDU agent actions addressed in the *Envision* policy scenarios may include a variety of management practices including clear-cut harvest, thinning, riparian protection, fertilization, hazardous fuel management, etc., and may be selectively applied to forests with different characteristics (ownership, age class, etc.). A first demonstration of using *Envision* with these draft COF scenarios will be conducted for a ~2000 km² study area surrounding the H.J. Andrews Experimental Forest in western Oregon (referred to as “*Envision* Andrews”, <http://envision.bioe.orst.edu/StudyAreas/Andrews/andrews.htm>). This area is forest-dominated, but contains a mix of private and public forest land with various stand ages, as well as some development. Spatial data layers on land use/land cover, physiography, soil characteristics, etc. have been developed. A small group of simple ES models linked to *Envision* will be used to demonstrate its capabilities for projecting changes in this landscape and in productions of ESs in response to specified COF scenarios.

Building on the experience from this test case, we will move forward on a number of fronts: we will (1) participate in workshops with representatives from federal, state, and private (including industrial) forest stakeholders to refine COF policy scenarios for the different sectors; (2) expand and refine the models linked to *Envision* to assess interactions among COF, pTEC_{max}, and the ESs, as more fully discussed in Tasks 3-6; and (3) expand the geographic coverage to include the entire WRB.

GCC Scenarios

Future climate change data produced by General Circulation Models (GCMs) typically are produced for one degree grids, too coarse to meet the goals of COFFEE. Data produced for this scale also have hindered sub-regional and state assessments, and prohibited developing useful tools for evaluating

policies for regions (e.g., the PNW). Therefore, high resolution climate data representing realistic scenarios are needed.

Initially, we will use nationwide climate change scenarios that are being prepared by NCEA under GCRP, in conjunction with the North American Regional Climate Change Assessment Program (www.narccap.ucar.edu/). These scenarios are being created by running a set of regional climate models (RCMs) nested in a set of atmosphere-ocean GCMs covering the U.S. and Canada. The scenarios will cover the period 2040-2070, with temporal resolution of 3 hours and spatial resolution of 50 km. This spatial resolution is high compared with outputs of GCMs without imbedded RCMs, so it will be necessary to do further downscaling to meet the needs of various spatially explicit models we will use in COFFEE. In the longer term, NERL under the leadership of Dr. Jon Pleim, RTP, is leading an effort to produce high resolution downscaled climate data to use in process models, including their own for air quality. The purpose of the project is to develop a coordinated effort within EPA to establish recommended approaches for dynamical and statistical downscaling focusing on key climate variables needed across the environmental assessments. For example, evaluations can focus on precipitation extremes for water-related assessments, stagnation and temperature extremes for air quality, etc.

Task 2 – COF Scoring Metrics and Scaling to Landscapes

We need metrics to score COF relative to estimates of quantified changes in ESs. Task 2 will develop such metrics, and also develop improved representations (maps) of various landscape attributes. Two site-specific metrics for TEC will be developed to score COF practices: (1) **current-climate** pTEC_{max} and (2) **future-climate** pTEC_{max}. Scoring of COF will be done by comparing the trajectory of a site to achieve these metrics in the presence and absence of implementing COF practices. Developing landscape representations generally involves using data collected at plots and mathematically creating representations at other scales (e.g., stands, sub-watersheds, watersheds, the WRB). We will do this because spatial databases are needed to support the modeling activities of COFFEE (e.g., VELMA) and WESP (e.g., *Envision*).

Task 2 has three parts. Firstly, we will develop a map of **current-climate** pTEC_{max} for the coniferous forested areas of the WRB while evaluating the assumptions of a method utilizing current soil C to estimate **current-climate** pTEC_{max}. Secondly, we will examine existing literature and incorporate data from EPA's LTEM transect sites [see Lee et al. (2007) for site locations and characteristics] to populate a data set to characterize trajectories of sites undergoing COF practices to attain **current-climate** pTEC_{max} starting from TEC at present. EPA's LTEM transect sites allow us initiate the same as above for sites to attain **future-climate** pTEC_{max} under COF and future climate scenarios (at least regarding extant variations in temperature and precipitation). Lastly, we will develop and test methods to scale results from plots to larger scales to produce spatially explicit representations of **current-climate** and **future-climate** pTEC_{max} and other site attributes.

Task 2 will address five of the major science questions of COFFEE:

1. What are the relevant forest ecosystem C and N processes and pools (aboveground, belowground, and per various quality fractions) that may be used to assess the potential of a parcel of coniferous forest land to sequester total ecosystem carbon (i.e., pTEC_{max})?

2. What are the relationships between $pTEC_{max}$ and its various component pools, and consequent changes in ESs?
3. What is the potential for a parcel of coniferous forest land, under current climate conditions, to sequester C (i.e., what is **current-climate** $pTEC_{max}$)?
4. How will future scenarios of atmospheric CO_2 concentrations and GCC alter **current-climate** $pTEC_{max}$ (i.e., what is **future-climate** $pTEC_{max}$)?
7. How can our projected outcomes for trade-offs among ESs due to COF practices and future changes in atmospheric CO_2 and climate change scenarios be scaled/extrapolated to the entire WRB?

Staff from ESD and WED will work collaboratively. Most of the geographic information system (GIS) and terrain analysis will be led by ESD staff, while most of the field and empirical work will be led by WED staff.

Task 2.1: COF Scoring Metrics

COF is intended to maintain and/or increase stocks of C sequestered in both above- and belowground pools, i.e., TEC, through increasing its various pools and altering related processes. We will use the metrics **current-climate** and **future-climate** $pTEC_{max}$ to score COF and evaluate effects of future GCC scenarios, thus allowing us to link quantitative outcomes of COF and GCC to quantified changes in production of ESs. We need a reliable method to estimate both metrics of $pTEC_{max}$ so we can produce spatially explicit representations (e.g., maps, and data layers that become model inputs) of stand attributes across the WRB. Homann et al. (2005) developed a method to calculate **current-climate** $pTEC_{max}$ using easily measurable properties of soil C. Should this method be as robust as suggested, we will have a reliable approach to use. However, the Homann et al. (2005) method is based on assumptions, and sampling and data analysis designs that require additional investigation and refinement before we would be confident in applying it across the WRB. Information to develop spatially explicit representations of **future-climate** $pTEC_{max}$ is limited and we will rely on data we collect at our research sites (e.g., EPA's LTEM transect sites) and from the literature, and capabilities provided by using various extant models.

Task 2.2 Assessing Trajectories of TEC with Regard to GCC and COF Practices.

The primary purpose of this task is to address uncertainties in the trajectories of forest growth and mortality with respect to changes in TEC over time and the consequences to ESs. Soils and terrestrial vegetation represent the second and fourth largest pools of C in the biosphere, respectively (IPCC 2007; Schlesinger 1997). Climate change, which may affect seasonal timing and magnitude of plant available soil moisture and temperature, may also affect the trajectory of TEC. Moreover, COF could exacerbate or ameliorate these climate effects. In order to evaluate how climate and COF influence TEC through forest growth and mortality, and soil C, a better understanding of how these factors are related to each other and to climate variation is needed.

Net primary production and decomposition processes greatly control the accumulation of TEC; and in PNW forests C sequestration in trees is one of the larger TEC compartments. Most existing forest growth models were developed considering only current climate conditions, and may not reflect growth under altered future climates. Therefore, knowing what local climate factors will most

influence forest growth and mortality, and the sensitivity of those local factors to global climate change will decrease uncertainty in estimating expected changes in TEC and other ESs.

Summer drought is the predominant climate feature affecting structure and function of unmanaged, naturally regenerated PNW forests (Waring and Franklin 1979). Stand density, growth, and reproduction are strongly related to plant available soil moisture and temperature in the PNW. Forests in this region efficiently use limited summer soil moisture that was accumulated during the previous winter and spring. GCC not only will affect average climate, but also seasonal climate patterns (e.g., warmer, wetter winters, and hotter, drier summers).

The goal of COF is to remove CO₂ from the atmosphere and sequester C via biological fixation. The short-term trajectory in change of TEC due to implementing a COF practice may not be maintained in the longer-term. For example, efflux of CO₂ via decomposition of more labile TEC pools due to initial disturbance may exceed annual primary productivity. This result will be transient for varying lengths of time depending on site conditions, and the nature of the COF prescription. Site conditions are highly variable in the WRB (Remillard 1999) including: soil type, C/N, total N, and seasonal patterns of temperature, and precipitation. The trajectory of TEC over time will depend on the rates of C loss and gain as the structure of the ecosystem changes relative to the intensity and frequency of COF practices. For example, depending on how much coarse woody debris (CWD) remains on-site, forest floor and mineral soil C/N ratios will be altered, affecting mineralization and mobilization of N, and annual primary productivity (Janisch and Harmon 2002).

Understanding relationships among site characteristics, GCC and COF prescriptions are needed to estimate changes in trajectories of **current-climate** and **future-climate** pTEC_{max}. What we know about estimating **current-climate** pTEC_{max} is based primarily upon work done in old-growth stands in Washington and Oregon (Homann et al. 2005); the trajectory likely is curvilinear for the first 150 years following disturbance and then becomes asymptotic thereafter (Janisch and Harmon 2002). Janisch and Harmon (2002) also describe successional changes in live and dead wood C stocks following disturbance and their effects on TEC. The amount of CWD left on-site is crucial for knowing the rate and extent of TEC accretion. For reasons discussed above, it is possible that Coast Range forests may reach **current-climate** pTEC_{max} more rapidly than Cascade Range forests. For example, we do not understand how slash decomposition and changes in TEC are related to COF for older- and younger-aged stands across a sufficient range of site conditions in the WRB.

Task 2.3: Scaling Landscape Attributes

One central component of Task 2 will be the up-scaling or down-scaling of data collected at one resolution, to a resolution suitable for process analyses and/or model development. Creating landscape representations of biophysical attributes (e.g., seasonally wet soils, amount of labile soil C) collected at plots requires extrapolating or interpolating these data to other scales of interest (e.g., watersheds, the WRB). Representations of attributes are important for the modeling activities of COFFEE and WESP. Thus, the outcomes of COFFEE models and *Envision* will depend, in part, on the accuracy of these data and extrapolated representations. Numerous statistical techniques are used to extrapolate/ interpolate point data across space and time, including multivariate regression, continuous (fuzzy) classification, geostatistics (kriging, cokriging), fractal methods, mathematical morphology and chaos theory, and numerical classification (decision and regression trees). While the

precise methods used depend upon the information being scaled, strategies and techniques are needed to take data obtained from classical plot experiments, and project them across a landscape or through time (Figure 2).

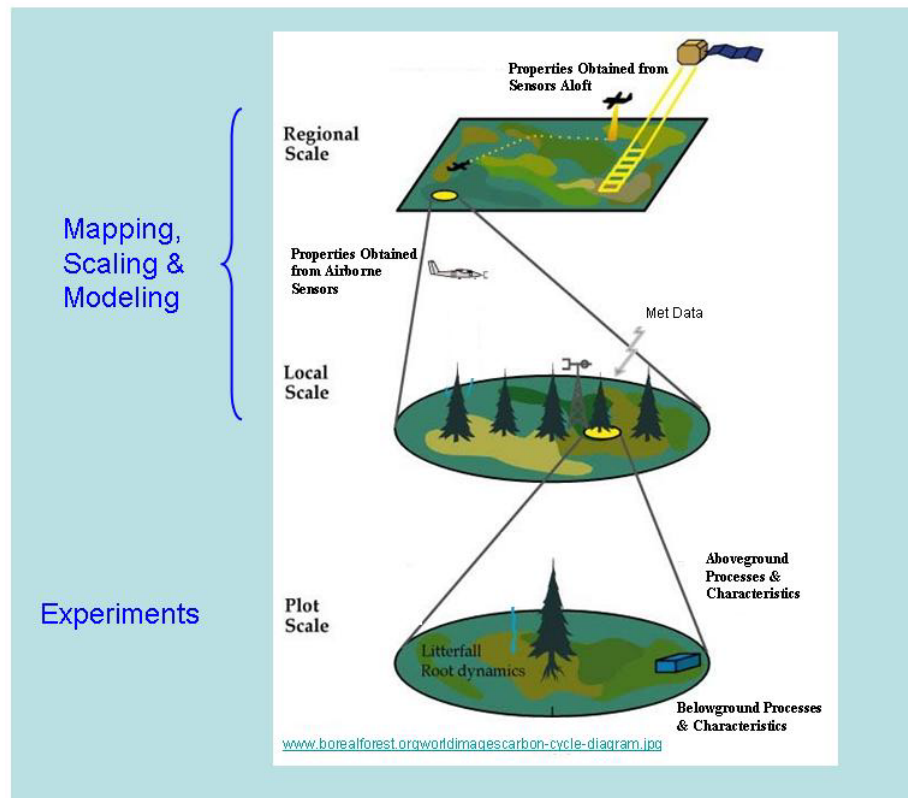


Figure 2. Generalized illustration of concepts to scale across space and grain.

Scaling is particularly challenging in heterogeneous landscapes such as the WRB. Quantitatively characterizing patterns of variation in these landscapes, as well as identifying underlying processes responsible for those patterns, are important to extrapolate results from experimental plots to larger scales. Improving our understanding of which factors regulate processes (e.g., how soil N affects plant growth) and how these factors are spatially distributed is essential for producing scalable outcomes (Bradford and Reynolds 2006). The simplest and most common way to stratify an area for spatial scaling is to divide it into homogenous regions (e.g., physiographic regions, Common Resource Areas, Ecoregions). By design, areas within a region share a narrow range of biotic and/or abiotic factors (e.g., temperature, precipitation, vegetation, soil, surface morphology). Thus, information obtained from plots within that region, with some degree of confidence, can be extrapolated across its extent. This concept has proven powerful to predict spatial distributions of landscape properties (Ator et al. 2005; Ator et al. 2003). In particular, with recent advances in remote sensing and Light Detection and Ranging (LiDAR) technologies, high spatial resolution spectral and topographic data show promise as accurate predictors for a range of biophysical properties.

We will evaluate methods to identify relatively homogeneous terrain attributes, with discrete properties, that repeat across WRB landscapes using hyperspatial (i.e., 0.6 m resolution) remotely sensed imagery, LiDAR, and environmental and other data layers. Developmental work will be done in the Panther Creek watershed; a 2500 ha forested catchment located west of McMinnville, OR on

the eastern slopes of the Coast Range. LiDAR data from Panther Creek are being collected as part of a multi-entity collaboration that includes scientists from public [EPA, National Resources Conservation Service (NRCS), Bureau of Land Management (BLM), USFS & OSU] and private (Weyerhaeuser Company & other land owners) interests. The collaboration will provide databases on aboveground biomass and soil C, and methodology to produce accurate, verifiable inventories of soil C. Panther Creek data on forest vegetation, soil chemistry and physics, updated soil survey, terrain analysis and digital soil mapping will be used to scale/extrapolate results from Panther Creek to the rest of the Coast Range.

Task 3 – Effects of COF and GCC on Biological Greenhouse Gas Regulation

Ecosystems play a key role in controlling chemical forms, transport rates, and fates of many GHGs, and it is important to understand the underlying processes to predict whether ecosystems will be sources and/or sinks of GHGs. Soils and terrestrial vegetation represent the second and fourth largest pools of C in the biosphere, respectively (IPCC 2007; Schlesinger 1997). Forest managers use various stem density prescriptions to achieve desired objectives for habitat, timber, and fire risk, and these prescriptions will be a major feature of COF; however, the prescriptions will also influence a range of GHGs in addition to CO₂. Climate change may affect seasonal timing and magnitude of plant available soil moisture, and seasonal patterns in atmospheric and soil temperatures, thereby altering emissions and sequestration of greenhouse gases. Changes in soil moisture also are likely to alter microbial activity, which could lead to increased oxidation of C and altered nutrient cycling. Similarly, any increase in temperature may result in changes in soil C quantity and/or quality, consequently altering soil physical characteristics which can influence water holding capacity and hillslope hydrology. As temperature and precipitation patterns change in response to climate change, it is possible that there will be shifts in forest soil and vegetation characteristics that will influence GHG fluxes. Despite the large role these compartments and processes play in biospheric GHG regulation, little is known about the magnitude and timing of GHG fluxes from most PNW forested ecosystems. Moreover, given that the COF policy may affect essentially all ecological processes in varying degrees (hydrological, biogeochemical, population dynamics, fire frequency and intensity, etc.) it could also exacerbate or ameliorate how climate affects BGHGR. In order to evaluate how climate and COF will influence fluxes of GHGs, a better understanding of the relationship among these complex processes is needed.

Soils represent one of the largest and least understood reservoirs of C and other potential GHGs, annually releasing roughly 10-times more CO₂ to the atmosphere than does fossil fuel burning (Amthor 1995). Even though there are good data for fluxes of some GHGs, there are insufficient data to produce ecological response functions (ERFs) in complex forested landscapes such as found in the WRB, for use with models that would then accurately predict effects of COF on soil C pools and BGHGR, particularly for fluxes of N₂O and CH₄. Denitrification, in which dissolved soil NO₃⁻ is biologically transformed to gaseous nitrous oxides and N₂, plays a major role in reducing terrestrial inputs of NO₃⁻ to streams, the regulation of which is an important water quality ES. Incomplete denitrification, however, results in N₂O release, which is a potent GHG with nearly 300-times greater atmospheric warming potential than CO₂. Denitrification rates vary greatly across landscapes and are affected by numerous factors including soil moisture, temperature, and soil C. Recent results suggest that the quality and quantity of soil C influence populations of denitrifying bacteria and denitrification efficiency (Kramer et al. 2006), as well as methanogenesis. Methanogenesis occurs in anaerobic soils and leads to release of CH₄, a GHG with 21-times greater warming potential than

CO₂. Unfortunately, either the research published on denitrification and methanogenesis involves agricultural and grassland ecosystems (Gregorich et al. 2006; Hungate et al. 1997; Mummey et al. 1998; Rochette et al. 2008), or the literature for forests did not sufficiently consider our interests in the edaphic and temporal conditions in the WRB (e.g., hillslope position, time since harvesting, relationships with quantity and quality of soil C, etc.).

This task will involve collecting data and using models to relate soil GHG flux to edaphic factors. The modeling component has two phases. In phase 1, COFFEE will work closely with WESP to evaluate ERFs between soil characteristics and regulating important GHG fluxes in the WRB. This effort primarily will involve data mining to evaluate available published literature. In some cases, data to construct ERFs already may be available. In cases where data to construct ERFs are unavailable for forest soils, data from other ecosystems will be used. Using this baseline, WESP will simulate GHG release in different land-cover/land-use types throughout the WRB. In phase 2, models will be used to simulate effects of GCC and COF practices on release of GHGs from soils. *Envision* outcomes will allow EPA clients to assess trade-offs and net benefits of a range of potential regulatory actions on GHG regulation, particularly VOCs, N₂O, CO₂, CH₄ and O₃.

Primarily, this task will address important data gaps relating specific metrics of TEC pools and processes to understand how COF and GCC may affect BGHGR and other ESs. In addition, the research outlined will provide improved input data for *Envision* plug-ins, and evaluate/validate outcomes of *Envision* based on collected field data. This task addresses the first major science question of COFFEE:

1. What are the relevant forest ecosystem C and N processes and pools (aboveground, belowground, and per various quality fractions) that may be used to assess the potential of a parcel of coniferous forest land to sequester total ecosystem carbon (i.e., pTEC_{max})?

Task 4 – Effects of COF and GCC on Air Quality Regulation

Ecosystem processes affect air quality by absorbing and emitting air pollutants or through indirect effects on their concentrations. The resultant benefits that humans derive encompass the ESs referred to as “air quality regulation” (Millennium Ecosystem Assessment 2005). Of particular interest to EPA are “criteria air pollutants” recognized by the Clean Air Act (CO, N₂O, O₃, SO₂, particulate matter, and Pb). EPA needs to understand the ways in which ecosystems help regulate air quality, how this ES varies with the extent and structure of forests resulting from C offset policies and climate change, and the economic value of these services. This task addresses COFFEE major science question 2:

2. What are the relationships between pTEC_{max} and its various component pools, and consequent changes in ESs?

Tree canopies absorb air pollutants (such as CO, NO₂, O₃, SO₂, PM) thereby providing economic human health and environmental benefits. While trees absorb these air pollutants, they also emit volatile organic compounds (VOCs), which are a precursor in O₃ formation. Thus, the net effect of trees on O₃ concentrations depends not only on their absorption of O₃, but also on their VOC

emissions. The importance of VOC emissions in regional air pollution also is relative to their significance as a limiting factor in O₃ formation compared with NO_x.

The USFS and collaborators have developed the i-Tree suite of models to evaluate ESs and economic benefits provided by trees in urban environments (www.itreetools.org). While urban forests represent only a small portion of biomass C in the WRB, many municipal programs aim to further develop “green infrastructure” by increasing tree cover within cities, one objective of which is mitigating GHGs by sequestering C. In developing C markets, cities may consider selling C credits to fund such green infrastructure developments. In addition, effects of urban trees on other ESs may be large relative to their minor status in basin-wide C pools because the majority of the population in the WRB lives within cities. In our analysis we will use one of these models, i-Tree Eco [formerly UFORE] (Nowak and Crane 2000), to assess air pollutant removal (and VOC emissions) and its economic value by trees in one or more urban areas within the WRB, based on individual tree data from inventories and/or random plot samples. A second model, i-Tree Vue, which is in a beta test version, will be used to assess air pollutant removals and their economic value basin-wide based on synoptic National Land Cover Data (NLCD) for the WRB.

These initial assessments will be based on current forest conditions in the WRB. However, the distribution and structure of forests are expected to change in response to policies encouraging forest C offsets, as well as by climate change. Additional i-Tree model analyses will be made for these future scenarios of forest condition and results will be compared with current condition assessments. Two types of comparative assessments are being considered. The first is essentially a non-spatial sensitivity analysis examining changes in air pollutant removals and economic benefits associated with hypothetical scenario changes (e.g., specified % increases in urban tree cover as a result of urban forestry policies, specified % increases in basin-wide forest cover as a result of afforestation, specified changes in forest age structure as a result of altered forest management practices, etc). A second assessment involves developing spatially explicit scenarios of forest distribution and structure under specified policy and/or climate change scenarios. *Envision* will be used to provide potential future land use/land cover maps under these scenarios, which can be used as input for i-Tree analyses of air pollutant removals and benefits.

Another area in which forests impact air quality is through forest fires, which emit both GHGs and other air pollutants. COF practices and climate change could affect the frequency and intensity of forest fires. One current question regarding C offsets revolves around whether or not removing biomass to manage fire risk will increase or decrease TEC over the long-term. Some argue that C sequestration rates are maximized by taking a hands-off approach, since forest fires only release a portion of the biomass and organic soil C pools, which may not exceed gains by avoiding biomass removals (Mitchell et al. 2009). On the other hand, others argue that biomass removals to manage hazardous fuels increase long-term gain of TEC because of reduced losses due to forest fires (Hurteau et al. 2008; Hurteau and North 2009). This question also impinges on the issue of “permanence” in establishing valid C offsets under developing C offset rules. If resources permit, we will address the potential for various COF practices to impact air quality through changes in forest fire emissions. Initial evaluations may include reviews of existing literature, as well as summarizing current ongoing research in this area such as modeling studies on climate change and fire in the WRB by Johnson et al. (Johnson et al. 2009), and experimental and modeling studies being conducted on fuel reduction practices in Oregon by WESTCARB (www.westcarb.org), etc.

Task 5 – Effects of COF and GCC on Water Quantity and Quality Regulation

Forest watersheds in the Cascade and Coast Ranges supply most of the freshwater used by humans in the WRB. This water provides a number of vital services, including provisioning of drinking water, habitat for fish and wildlife, recreational opportunities, and irrigation of agricultural lands.

Consequently, policymakers, land managers and the public are intensely interested in effects of forest management and climate change on the quantity and quality of water that forest ecosystems provide. Effects of forest management on water quality and quantity are reasonably well established, and current forest practice laws are designed to reduce negative impacts

(<http://www.oregon.gov/ODF/privateforests/docs/guidance/FPArulebk.pdf>). In contrast, there is a good deal of uncertainty concerning future changes in climate and consequent effects on the quantity and quality of water that forests will supply in coming decades. For example, some projections point to significant declines in winter snowpack and spring runoff (Mote 2003), potentially leading to severe summer water shortages and drought stress. The need to address these uncertainties is especially urgent given the projected population growth of more than 1.7 million (+74%) in the WRB from 1998 to 2050 (<http://docs.lcog.org/wvlf/info.html>). In particular, it is important to understand how potential changes in climate and forest management practices will interact to affect future supplies of clean water. That is, for any given climate scenario, will specific COF practices significantly increase or decrease the discharge of water, nutrients, sediments, pesticides and toxics from forest lands in the WRB? This task addresses two COFFEE major science questions:

2. What are the relationships between $pTEC_{max}$ and its various component pools, and consequent changes in ESs?
6. For alternative COF policy scenarios (e.g., business as usual, maximized C sequestration, and maximized extraction of forest products), what are the trade-offs among the ESs of interest to COFFEE?

There is a rich history of scientific studies in the PNW addressing effects of forest management on water quality and quantity, including long-term monitoring of stream discharge and chemistry for watersheds in the Cascade Range (e.g., “*Envision Andrews*”

<http://envision.bioe.orst.edu/StudyAreas/Andrews/andrews.htm>) and Coast Range (e.g., Alsea Watershed Study, <http://www.ncasi.org/programs/areas/forestry/alsea/default.aspx>). Consequently, there is not a pressing need for new experimental work. Instead, this task will rely on data mining of existing scientific literature to obtain hydrologic data and ERFs that WESP requires for modeling effects of COF and climate on stream water quality and quantity. WESP already has assembled many of these water quality/quantity data sets, and incorporated and validated the ERFs for climate and land use into VELMA, a spatially-distributed eco-hydrologic model that simulates the integrated responses of multiple ESs (regulation of water quality and quantity, C sequestration, GHGs, etc.) to interacting stressors. Remaining work in this area will focus on (1) defining C and water ERFs specific to COF practices, (2) specifying COF “decision rules”, and (3) modeling long-term changes in water quality/quantity throughout the WRB in response to alternative COF scenarios. The COFFEE and WESP projects will work in close coordination on the data mining effort to define water quality/quantity ERFs specific to COF practices. COFFEE primarily will be responsible for specifying COF decision rules (harvest methods and intervals, stream buffers, etc.) in the context of air and water quality regulations, C markets, and other considerations. WESP will be responsible for

implementing these decision rules in *Envision* to simulate effects on water quality/quantity throughout the WRB. Water quality/quantity parameters of interest will include stream temperature, and loadings of nutrients (dissolved and suspended forms of C, N, and P), sediments, and toxics (Hg and pesticides), and peak (storm) flow and base (summer) flow.

Task 6 – Effects of COF and GCC on Wildlife Populations and Habitat Suitability

Envision will be used to represent plausible COF scenarios and then project landowner responses to these scenarios in their land use and management decisions. The resulting alternative future landscape maps will be used as inputs for models used in this task that assess habitat distribution and wildlife population responses as a function of spatial distributions of land use types. Several such models were utilized previously to examine habitat and wildlife responses to three alternative development trajectories constructed in the WAFP (Baker et al. 2004; Hulse et al. 2002). We plan to do similar assessments with the models described below, using the land use projections from *Envision* for alternative COF scenarios in place of the three alternative development projections from the earlier WAFP.

COFFEE will lead developing alternative future landscapes and deriving habitat maps from these products. WESP will lead the wildlife response modeling work, which will be based upon future landscape scenarios provided by COFFEE. The activities in this task address COFFEE major science questions 2 and 7:

2. What are the relationships between $pTEC_{max}$ and its various component pools, and consequent changes in ESs?
7. How can our projected outcomes for trade-offs among ESs due to COF practices and future changes in atmospheric CO_2 and climate change scenarios be scaled/extrapolated to the entire WRB?

There are two sets of activities in Task 6.

Task 6.1 – Predicting Changes in Habitat Structure

Forest management has profound effects on wildlife habitat quality, including effects on stand structure (e.g., species composition, size-class distribution, 3-D spatial structure, presence of “snags”) and landscape-scale spatial patterns (e.g., habitat connectivity and fragmentation, migration corridors, riparian buffers). For example, late successional forest habitats favor such threatened and sensitive wildlife species as spotted owls, pileated woodpeckers, and flying squirrels and other small mammals. On the other hand, early successional habitats favor important species such as elk, deer, and a wide variety of songbirds. Since the *Northwest Forest Plan* was officially adopted in 1994, forest management practices increasingly have been used to improve habitat conditions for a variety of species, while still achieving goals for timber production and C sequestration. For example, the practices of variable density thinning, understory enrichment and snag protection are being used to achieve these multiple objectives in PNW forests (Carey and Harrington 2001; Harrington et al. 2005; Reutebuch et al. 2004) see <http://www.fs.fed.us/r6/olympic/ecomgt/research/habitat.html>) Because these and similar studies generally are in their early stages, it is difficult to extrapolate in

space and time how successful specific practices will be to achieve habitat and wildlife population goals.

Habitat and wildlife simulation models increasingly are being used to address this need. For example, McRae et al. (2008) used a forest plant community model [FORCLIM] (Busing and Solomon 2005; Busing and Solomon 2006; Busing et al. 2007) in combination with a spatially-explicit, individual-based wildlife population model [PATCH] (Schumaker et al. 2004) to assess how alternative forest management and GCC scenarios will affect early and late-successional songbird populations during the next 100 years in the 500 km² Upper South Santiam Watershed on the western slopes of the Cascade Range. Similarly, multi-model frameworks have been used to simulate forest management effects on habitat quality and wildlife populations in the Coast Range (Johnson et al. 2007). However, existing models do not adequately represent key above- and belowground processes controlling long-term changes in forest stand structure in response to thinning practices. Because stand density management likely will be a major silvicultural practice to mitigate GHGs via increasing TEC, and manage habitat quality in PNW forests in coming decades (e.g., http://www.blm.gov/or/resources/forests/files/2009_report.pdf), it is important to understand and incorporate these controlling processes into well-integrated forest growth and habitat modeling frameworks.

We will conduct experiments to test and apply statistically-based Stand Density Response Functions (SDRFs) to predict effects of COF, specifically stand density management, on spatial and temporal changes in forest habitat structure. By representing size- and density-dependent competition among individual trees for above- and belowground resources (light and CO₂, and nutrients and water, respectively), the SDRFs can be used to predict growth and mortality of individual trees during stand development. Thus, we will use the SDRFs to predict successional changes in 3-D structure and biomass distribution within forest habitats, including sizes and spatial distributions of live and dead snags by species, and C allocation to leaves, stems and roots. Predictions will address COF effects on forest habitat structure from stand inception to old-growth.

Firstly, we will calibrate and test the SDRFs using detailed stand-level data for a range of WRB forest types and ages. This is necessary because our proof-of-concept SDRFs were developed for old-growth forests on the western slopes of the Cascade Range (McKane et al. 2004a; McKane et al. 2003; McKane et al. 2004b). Therefore, we will conduct experiments in young and old WRB stands in the Coast and Cascade Ranges to calibrate the SDRFs for the entire WRB. We will use selected sites along the EPA LTEM transect, on the Sweet Home and Blue River Ranger Districts of the Willamette National Forest (Cascade Range: <http://www.fs.fed.us/r6/willamette/manage/big-blue/index.html>), and at the BLM-USFS Stand Density Management study (Cascade & Coast Ranges: <http://www.fs.fed.us/pnw/research/lse/initial-thinning.shtml>). The mix of sites used will be determined based on needs to collect sufficient data for experimental design and statistical modeling requirements. We anticipate setting up extensive (up to 15) and intensive (up to 6) sites across the candidate locales, pending discussions with USFS and BLM staff. Extensive sites will be larger (~5 hectares), and will be surveyed (dbh, height, crown dimensions, stem increment, and stem mapping) one time only to assess stand density responses less rigorously than what will be done at the intensive sites. Intensive sites (~1 hectare) will be instrumented with climate sensors and resurveyed after 3 years to allow for a more rigorous assessment of responses to thinning treatments.

Secondly, we will use the individual-based SDRFs to develop much simpler Patch-Scale Response Functions (PSRFs) at the scale of habitat “patches” (e.g., 30 x 30 m or larger) employed by the HexSim wildlife population model (HexSim User’s Manual, *in preparation* by Schumaker). This step is necessary because SDRFs would be computationally too slow to extrapolate COF-driven habitat dynamics across the entire WRB. Using well-established procedures for developing aggregated models (Williams et al. 1997), we will derive a simple set of patch-scale ERFs from the fine-scale dynamics predicted by the individual-based SDRFs. Typically, such aggregated models are computationally many orders of magnitude faster. Spatial and temporal extrapolation of the PSRFs for the WRB will rely on GIS data layers being developed for COFFEE [i.e., land use (COF practices), plant community/habitat type, climate, and soil characteristics].

Task 6.2 – Habitat Indices

Task 6.1 describes a process-oriented approach of developing Stand Density Response Functions and Patch-Scale Response Functions to describe fine-scale responses to COF management practices and use those to drive a wildlife population model for estimating COF effects on a selection of individual wildlife populations. Task 6.2 will take a complementary approach, focusing on coarser scale indices of habitat availability and condition, based on spatial patterns of land cover classes currently and under COF scenarios.

Approach:

Several methods have been used to assess indices of (a) biological condition of streams, and (b) terrestrial vertebrate habitats under three alternative development trajectories constructed in the WAFP (Baker et al. 2004; Hulse et al. 2002). Using these methods we plan to do similar assessments based on current land cover, and land cover projections from *Envision*, for specified COF scenarios. (Task 1). Thus, *Envision* will provide the vegetation (land cover) changes that reflect landowner responses to COF policies and natural processes such as succession. In turn, the methods described below will use these future landscape maps to project the effects that these vegetation changes and their spatial patterns have on various indices of habitat and biodiversity. These methods are appropriate for examining the effects of COF scenarios under current climate, but will not be used for similar assessments under climate change scenarios since the indices are empirically derived under current climate conditions only.

Biological condition of streams – We will use the five regression models developed by Van Sickle et al. (2004) to estimate indices of fish and aquatic invertebrate communities in 2nd to 4th order streams in the WRB as a function of physiography, stream flow, and land use/land cover. These indices include:

1. Native fish species richness – This reflects the overall biodiversity of the system and impacts of human disturbances causing loss of native species through water temperature alteration, siltation, toxic chemicals, introduction of non-native species, or other changes in stream habitats (Hughes et al. 1998).
2. Index of Biotic Integrity (IBI) – This index assesses alterations in composition and functional organization of fish communities relative to that expected in the absence of human disturbance (Hughes et al. 1998; Karr 1981).
3. Cutthroat trout abundance – This species is the most widely distributed salmonid species in the WRB.

4. EPT richness – This estimates the total number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) genera in the macroinvertebrate community, which are relatively intolerant of silt, warm temperatures, and water quality degradation (Barbour et al. 1999).
5. Willamette Invertebrate Observed/Expected (WINOE) index – This is the percentage of macroinvertebrate taxa at a site that were also found at two or more minimally disturbed reference sites.

Terrestrial vertebrate habitats – We will use a simplification of the methods of Schumaker et al. (2004) and Polasky et al. (2008) whereby habitat suitability ratings are assigned to each land cover type that reflects the relative preference of a species for breeding in that land cover type. This will be done for all 279 terrestrial vertebrate (i.e., bird, mammal, reptile, and amphibian) species currently or historically breeding in the WRB. Each Independent Decision Unit (IDU) from *Envision* will be assigned a habitat score based on the suitability rating and the geographic range of the species. For each species, summing these scores across all the IDUs in the WRB reflects the total suitability-weighted habitat area. These basin-wide species habitat scores can then be summed for various groups of species (e.g., birds, mammals, reptiles, amphibians).

A4 Quality Objectives and Criteria for Measurement Data

While the COFFEE Research and Implementation Plan has been structured along related scientific goals and activities, this structure does not lend itself easily to organize the project for purposes of describing how to meet WED QA/QC requirements. Given all the diversity of activities within and across COFFEE Tasks, the activities can be organized into four broad, overarching categories that more easily allow us to address the required QA/QC elements. The four Appendices will serve the purpose of describing the QA/QC elements required in this QAPP in the following categories of activities:

Appendix 1. Scenarios Development

Responsible COFFEE PI - Donald Phillips

Appendix 2. Spatial Analysis

Responsible COFFEE PI - Mark Johnson

Appendix 3. Collecting Primary Data

Responsible COFFE PI – Christian Andersen

Appendix 4. Modeling

Responsible COFFEE PI – Paul Rygiewicz

A5 Special Training Requirements/Certification

Medical monitoring, and any field/outdoor safety training for staff who will do field work will be required. This monitoring and certification will be overseen by WED's Health and Safety Officer.

A6 Documentation and Records

Aspects of COFFEE work pertaining to a participant's daily activities in the project will be documented in the notebooks provided to each participant by the appropriate QA Manager (WED/ESD). Documentation and record keeping of results of SOP activities will be maintained on a

computers attached to analytical (as per those capabilities), on computer drives of the relevant PI or other researcher, and in the COFFEE folder on the WED “L” driver server, or its successor. Documentation and record keeping pertaining to specific SOPs will be as per the procedures specified in the SOP. Other elements that are related to all the activities within the four overarching categories, are described in the four Appendices.

B. MEASUREMENT / DATA ACQUISITION

As noted above, the QA/QC elements required for the QAPP are presented in each of the four Appendices describing overarching categories of activities that will be done on the COFFEE project. The four Appendices serve the purpose of describing the QA/QC elements required in this QAPP:

Appendix 1. Scenarios Development

Responsible COFFEE PI - Donald Phillips

Appendix 2. Spatial Analysis

Responsible COFFEE PI - Mark Johnson

Appendix 3. Collecting Primary Data

Responsible COFFE PI – Christian Andersen

Appendix 4. Modeling

Responsible COFFEE PI – Paul Rygiewicz

B1 Sampling Process Design (Experimental Design)

B2 Sampling Methods Requirements

B3 Sample Handling and Custody Requirements

B4 Analytical Methods Requirements (including statistics if appropriate)

B5 Quality Control Requirements

B6 Instrument/Equipment Testing, Inspection, and Maintenance Requirements

B7 Instrument Calibration and Frequency

B8 Inspection/Acceptance Requirements for supplies and Consumables

B9 Data Acquisition Requirements (Non-direct Measurements)

B10 Data Management

C. ASSESSMENT / OVERSIGHT

C1 Assessments and Response Actions

Aside from specifics described in the four Appendices, each Task Leader will be responsible for overseeing QA related issues relevant in the respective Tasks, formulating any necessary remedial actions, and reporting progress and any QA issues to the Project Leader in a timely manner (anyway from immediately to a minimum of at the next Project Meeting). QA issues will be discussed at each Project Meeting so that the Project Leader will be able to inform management of the status of the project when asked. The WED QA manager, at times convenient to the project PIs will periodically (at least once) assess adherence of the various tasks to the prescriptions of this QAPP and its Appendices.

C2 Reports to Management

Each Task Leader will be responsible to report progress and any QA issues to the Project Leader in a timely manner (anyway from immediately to a minimum of at the next Project Meeting). QA issues will be discussed as each Project Meeting so that the Project Leader will be able to inform management of the status of the project when asked.

D. DATA VALIDATION AND USABILITY

If departures from the procedures specified below in this section are necessary, they will be included in SOPs for each type of data collected.

D1 Data Review, Validation, and Verification Requirements

All experimental data must be evaluated for accuracy by looking for missing or unusual values. Questionable data are noted with appropriate comments so that each such datum can be evaluated further as the data set is analyzed. Before data can be considered for statistical analysis, questionable values must be evaluated, and then each must be discarded or included in final data sets, accompanied by an explanatory comment describing the basis for the decision. QA control data will be evaluated for individual data sets to identify any overall problem(s) with the accuracy of the data. If the QA control data (e.g., of blanks, standards, control treatments) indicate an irreconcilable problem, the experimental data will not be used for further analysis. Only data that have been verified and validated by comparing with QA control data will be used for statistical analysis. When statistical analysis further indicates questionable outlier values, records relating to values must be reevaluated to see if there is an explanation for their unusual nature. Unless there is a verifiable reason why unusual values shall be omitted, they shall be included in statistical analysis and will be considered representative of normal experimental variability.

D2 Validation and Verification Methods

Individual scientists are responsible for checking data as they are obtained to insure accuracy of the data by looking for missing or unusual values. Comments which explain decisions to exclude or include such data in further analyses must be made in laboratory notebooks and data spreadsheets.

The main PI for each component of the project will be responsible for review, validation, and verification of data collected by others working in their component. When data are recorded by hand, the PI will review laboratory notebooks and spreadsheets into which data have been transcribed to insure accuracy of data transfer. The PI will make note on the hardcopy and in the electronic versions of the data that such a review was conducted and the transfer of the data was performed accurately [the accuracy notation will be accompanied by the date (both versions) and PI's signature (hardcopy)]. For data obtained electronically the PI will review the electronic data files for accuracy by looking for missing, or unusual values.

D3 Reconciliation with User Requirements

Early, frequent and open communication is needed when more than one individual may be the producer and user of any data. Collaborating participants must meet early during problem formulation and experimental design phases to insure that the data that will be collected will meet the requirements of anticipated, subsequent analyses procedures. Specific details regarding endpoints, frequency and format of the data will be prescribed before experimental work begins. Communication among participants in a research activity will continue on a regular basis through the scientific process, to the publication of reports and papers based on the research.

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Appendix 1. Scenarios Development

Date: October 1, 2010

Responsible COFFEE PI: Signature indicates Appendix is current as of the above date and will be implemented in conducting the research of this project.

Donald Phillips Donald Phillips 10/25/10
Signature Date

Project Leader: Signature indicates commitment to follow the procedures in this QAPP.

Paul Rygiewicz Paul Rygiewicz 10/25/10
Project Leader Signature Date

Quality Assurance: Signature indicates that this Appendix meets the quality requirements of WED.

Bob Ozretich Robert H. Ozretich 10/26/10
Quality Assurance Manager Signature Date

App1: Scenarios Development

The COFFEE project will address the effects on ecosystem services of scenarios for both carbon offset forestry (COF) and global climate change (GCC). These scenarios will be devised as described in the COFFEE Research Plan, Task 1 – Policy and Environmental Drivers. The QA approach for these scenarios is listed below:

App1: COF Scenarios

The QA approach is described in detail in the “QAPP for Evaluating Western Oregon Land Use and Forest Management Responses to Potential Carbon Storage Policies”, approved 11/24/09. This is the QAPP for an EPA/USDA Forest Service Interagency Agreement by the same title.

Don Phillips is the EPA Project Officer for this Interagency Agreement (IAG) and copies of documents related to it are maintained in his office. Electronic copies are also maintained on the WED computer network in L:\Priv\CORFiles\Projects\COFFEE\A_Task1 Don P et al\USFS IAG. These include official forms for establishing the IAG, the QAPP, progress reports, and notes from meetings discussing technical details of scenario construction.

App1: GCC Scenarios

In the near term, COFFEE will be utilizing nationwide climate change scenarios that are being prepared by EPA’s NCEA under EPA’s Global Change Research Program (GCRP), in conjunction with the North American Regional Climate Change Assessment Program (www.narccap.ucar.edu/). These scenarios are being created by running a set of regional climate models (RCMs) nested in a set of atmosphere-ocean general circulation models (GCMs) covering the U.S. and Canada. The scenarios will cover the period 2040-2070, with temporal resolution of 3 hours and spatial resolution of 50 km. Preparation of these data for EPA’s use is occurring under an Interagency Agreement entitled "Analysis of Climate Simulations from the North American Regional Climate Change Assessment Program (NARCCAP) for the Assessment of Potential Global Change Impacts on U.S. Water Quality and Aquatic Ecosystems" between EPA and the National Science Foundation (NSF), which in turn has agreements with the NARCCAP program in the National Center for Atmospheric Research (NCAR). Responsibility for Quality Assurance for this work has been assigned to NCAR per the IAG: “It has been decided that NCAR will handle all QA/QC requirements under this IAG, in accordance with NCAR guidelines, and taking into account supplemental suggested guidelines provided by EPA (also attached).” The pages of the IAG relevant to QA are provided in the attached document “narccap_iag_qa_pages.pdf”.

One of the program goals under the GCRP Multi-Year Plan that is currently being written is to develop an ORD Climate Scenarios group. This group would be responsible for acquisition of climate change scenarios from GCMs and other climate models, and for developing and applying methods for downscaling of climate scenarios for the higher spatial and temporal resolution required for many process-based models assessing climate change effects. In the longer term, the COFFEE project will rely on this ORD Climate Scenarios group for guidance and downscaled scenarios of climate change, including whatever QA procedures they develop.

Appendix 2. Spatial Analysis

Date: October 1, 2010

Responsible COFFEE PI: Signature indicates Appendix is current as of the above date and will be implemented in conducting the research of this project.

Mark Johnson



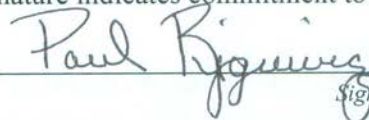
Signature

10.25.10

Date

Project Leader: Signature indicates commitment to follow the procedures in this QAPP.

Paul Rygiewicz
Project Leader



Signature

10/25/10

Date

Quality Assurance: Signature indicates that this Appendix meets the quality requirements of WED.

Bob Ozretich



Signature

10/26/10

Date

Quality Assurance Manager

App2: Spatial Analysis

Within the COFFEE Research Plan several research activities utilize spatial data. Some will use existing spatial data and in other instances spatial data sets will be developed as a part of the research. These spatial data will be utilized to meet the research objectives of the COFFEE project. This section provides information on the spatial data that will be used in Task 2 (COF Scoring Metrics and Scaling to Landscapes) and is divided into two parts. The first deals specifically with existing spatial data and the development of new spatial datasets. The second deals with the various analyses that are to be performed using spatial data.

App2: Existing Spatial Data

Table 1 lists many of the spatial databases available for use in the COFFEE project. These are databases created by others and readily available for use. In general, information about the source and quality of the data is in the associated metadata.

App2: New Spatial Data

Spatial databases will be created as a part of COFFEE. One that is crucial for a number of COFFEE analyses is SOC within the WRB. While a spatial database of SOC may be developed from existing soil databases (i.e., STATSGO, SSURGO), they lack the local specificity needed to provide an accurate inventory of SOC. The new COFFEE SOC spatial database will be developed by proportionally allocating new soil pedon laboratory data across a landscape following a detailed terrain analysis.

The terrain analysis operates on the assumption that surface morphology is a prime driver of many ecological processes. It strongly influences the flow of water and thus the flow of nutrients, sediments, and pollutants across the landscape. It also has a direct effect on the amount and timing of solar radiation that reaches an area influencing the local air and soil temperatures. These two components together often dictate the occurrence and composition of soil biological communities for any given locale. Using digital elevation model data for the specific area of interest, a variety of terrain attributes can be calculated for use in the terrain analysis including: slope, aspect, plan and profile curvature, catchment area, and flow path length. Using many of these measures as input, indices for soil wetness, stream power, solar radiation, topographic position, landforms, surface ruggedness, and temperature may also be computed within the ArcGIS Desktop software package and using the Terrain Analysis System (TAS) software tools developed by Dr. John Lindsay (<http://www.uoguelph.ca/~hydrogeo/TAS/index.html>). Documentation will be the key to recording the steps taken to complete the terrain analysis.

A number of statistical tools will be employed to sort and organize the results of the terrain analysis. One technique that has been used in this kind of research is Classification and Regression Tree (CART) analysis. CART has been shown to be particularly useful in selection the correct terrain attributes that influence or control the distribution of SOC across landscapes. We will use CART and other statistical tools to create a terrain and new pedon data based map of SOC. These will first be produced for small representative catchments in each of the WRB physiographic provinces before up-scaling the data for the entire physiographic province. Statistical attributes of the data [e.g.,

Coefficient of Variation (CV), also, see below in this Appendix] will be used to characterize the uncertainty in the final spatial databases.

App2: Specific Tasks that Employ Spatial Data or Spatial Analyses

Task 2 has two parts that utilize spatial data. The first is Task 2.1, COF Scoring Metrics. In this task the relationship between measures of soil organic carbon (SOC) and total ecosystem carbon (TEC) are used to make a WRB-wide map of potential maximum total ecosystem carbon (pTEC_{max}). This is contingent upon the robustness of the relationship between these two variables, as described in Homann et al. (2005), for the WRB. We will use “errors in both variables” regression analysis. If the regression is statistically significant at $P \leq 0.05$ then the regression will be used to make spatial estimates of pTEC_{max} and the map will be developed. Confidence intervals for pTEC_{max} can be estimated for spatial units such as soil map units, depending upon the map base used to generate the pTEC_{max} map. If they are robust, then the map will be developed. If they are not, then alternative measures of SOC and their relationship with pTEC_{max} will be considered and alternative maps developed. The second part is Task 2.3, Scaling Landscape Attributes. This task considers the procedures for the up-scaling or down-scaling of data collected at one resolution, to a resolution suitable for process analyses and/or model development.

App2: Spatial analysis in Task 2.1: COF Scoring Metrics

A fundamental part of Task 2.1 is testing the method for developing a map of pTEC_{max} as described by Homann et al. (2005). Should the method be robust for the WRB then the relationship between SOC in the top 20 cm of soil and pTEC_{max} will be used to create a map of pTEC_{max} for the WRB. The spatial analysis part of this task is the converting a map of SOC in the top 20 cm of soil in the WRB into a map of pTEC_{max}. The relies upon a map of SOC in the WRB. Most of the WRB is included in the SSURGO (Soil Survey Geographic Database from the NRCS and available at <http://soils.usda.gov/survey/geography/ssurgo/>). SSURGO is a spatial database of soil information based upon county-level soil surveys and is published at a 1:24,000 scale. SSURGO is the most locally accurate county-level database, but has only been completed for the western two-thirds of the WRB. The eastern third of the WRB is national forest land (Western Cascade Mountains) and the soils have not been mapped to SSURGO standards. They are, however, included in a coarser (1:250,000) spatial database. The STATSGO spatial database is available at <http://soils.usda.gov/survey/geography/statsgo/>. There is complete coverage of the WRB with soil information when the two databases are combined and STATSGO is used to fill in where SSURGO has no information. The WRB covers an area of 29,723 km². Of this, 9163 km², or 30%, is covered by STATSGO data and the other two thirds by SSURGO. Appendix 2 Table 1 lists all of the spatial data bases currently available to the COFFEE project. Appendix 1 Table 2 provides a listing of the GEOSPATIAL SOPS that may be used in the Spatial Analysis tasks.

For previous exercises to estimate SOC in the WRB we have worked with Steve Campbell with the USDA, Natural Resources Conservation Service (NRCS, Portland, OR) who calculated the SOC content of WRB soils to both 1.0 m and 1.5 m using the NRCS National Soil Information System (NASIS) software and the SSURGO and STATSGO databases for the WRB following the methods described in Johnson and Kern (2002). Calculations were made by horizon using bulk density and organic matter content. When data were reported as soil organic matter (SOM), a conversion factor

of 0.58 was used to convert SOM to SOC (Burt, 2004). When coarse fragments were present, a correction was made to account for the soil volume that is occupied by the coarse fragments and does not contain SOC. Calculations were also made for the amount of organic C held in the O-horizons (i.e. duff layer). Since the STATSGO database does not contain data for the duff layers, the average duff layer C content from SSURGO was used to estimate the C held in the duff of the soils in the WRB part of STATSGO. Mr. Campbell, NRCS, has agreed to assist with the data extraction and compilations of soil data from STATSGO and SSURGO that are needed for the COFFEE project. Mr. Campbell's position responsibilities at the NRCS include helping people use data generated by the NRCS. In the case of COFFEE, we will be using Soil Survey and Soil Laboratory data. Mr. Campbell has helped WED in the past and has agreed, via verbal agreement, to assist us again in the future. In the past, he followed the methods that Jeff Kern et al (1997) and Kern and Johnson (2002) published. We will document in COFFEE project notebooks and files all that he does. To assist with WRB calculation of $pTEC_{max}$ Mr. Campbell will create a spatial database of SOC for the top 20 cm of mineral soil across the WRB. We will work with Mr. Campbell to estimate the propagation of error (e.g., the coefficient of variation) in these calculations so that estimates of uncertainty can be included in the final spatial databases. These methods are described in Kern et al. (1997) and Johnson and Kern (2002).

App2: Task 2.3: Scaling Landscape Attributes

While Soil Surveys and linked laboratory data currently provide the best spatially distributed estimate of SOC, unfortunately this approach lacks specific local detail as soil physical and chemical information in these databases (e.g., STATSGO and SSURGO) is often from soils that were collected in other locations. Instead, we are taking the approach within the WRB to develop soil inventories that are specifically linked to the major physiographic provinces of the WRB and local soils data. The overall strategy for the WRB effort is to first obtain LiDAR data for the WRB. [LiDAR is a very fine resolution Digital Elevation Model (DEM) and will be used in a terrain analysis.] We have selected the upper reaches of the Panther Creek Watershed to serve as a "laboratory" for methods development and testing. Panther Creek is representative of the East slope of the Oregon Coast Range physiographic province, which accounts for about 20% of the WRB. Panther Creek is located in Western Yamhill County.

The ultimate goal of this activity is to identify the best procedures for creating spatial data layers (e.g., SOC, SON) for the WRB that can be used in the COFFEE project either to facilitate calculations or distribution of soil-based properties across the WRB (e.g., $pTEC_{max}$) or to be used as input to COFFEE modeling activities. Beginning with Panther Creek watershed we will create spatial databases of SOC using three different scales of data. The first will employ the STATSGO database with a scale of 1:250,000. The second will use the SSURGO database with a scale of 1:24,000. The third will be developed using terrain analysis in which we identify relatively homogeneous terrain attributes, with discrete properties, that repeat across landscapes using hyperspatial (i.e., 0.6 m resolution) remotely sensed imagery, LiDAR, and environmental and other data layers, with a scale finer than SSURGO. The three resulting spatial databases of SOC (i.e., STATSGO, SSURGO and Terrain Attribute) will be compared to identify the database with the lowest uncertainty.

The initial scaling developmental work will be done in the Panther Creek watershed and will focus on SOC. Panther Creek watershed is a 2500 ha forested catchment located west of McMinnville, OR on the eastern slopes of the Coast Range and is very data-rich due to ongoing collaborative research efforts there. The collaboration will provide spatial databases of above- and belowground tree biomass. In 2009, 35 soil pedons were excavated and sampled for a variety of analyses at the NRCS Lincoln Laboratory. This will allow us to explore a number of approaches for developing accurate, verifiable inventories of soil C. Panther Creek data on forest vegetation, soil chemistry and physics, updated soil survey, terrain analysis and digital soil mapping will be used to scale/extrapolate results from Panther Creek to the rest of the Coast Range.

Here is a general list of the steps involved in this analysis:

- 1) Identify physiographic provinces within the WRB;
- 2) Select sub-catchment for intensive study;
- 3) Gather relevant data layers and databases;
- 4) Conduct a systematic analysis of the sub-catchment terrain to identify the repeating components of the landscape;
- 5) Characterize the hydrogeomorphology of the sub-catchment and develop a conceptual understanding of how water moves through or is retained in the sub-catchment;
- 6) Develop a strategy (i.e., statistical sampling frame) for sampling sub-catchment soils and characterizing their variation across the landscape;
- 7) Create an inventory of above- and belowground carbon stocks through sampling and analysis leading to an assessment of the quantity and quality of these stocks;
- 8) Develop a Soil-Landscape-Climate model for predicting the distribution of soil carbon in the sub-catchment and ultimately, using a terrain-based extrapolation using the model, to the entire physiographic province;
- 9) Assess and quantify the effects of forest/land-use management on above- and belowground carbon storage and on water quantity and quality (e.g., temperature, dissolved and particulate carbon, nutrients, and other components);
- 10) Develop methods for scaling results from sub-catchments to the entire physiographic province, and ultimately the entire WRB.

Appendix 2 Table 1: Spatial datasets available for the COFFEE Project

Category	Dataset Description	Source/Desc	Data Format	Resolution/ Scale	Download Site/Contact/Metadata
ANTHROPOGENIC					
Agriculture	Cropland Data Layer	USDA/National Agricultural Statistics Service	grid	30 m	http://datagateway.nrcs.usda.gov/
GEOPHYSICAL					
Climate	Precipitation, Max. Temp.\Min. Temp.\Dew Point - Annual	PRISM Group	grid	4 km	http://www.prism.oregonstate.edu/products/matrix.phtml
	Precipitation, Max. Temp.\Min. Temp.\Dew Point - Monthly	PRISM Group	grid	4 km	http://www.prism.oregonstate.edu/products/matrix.phtml
Elevation	National Elevation Dataset 10 Meter	USGS	grid	10 m	http://seamless.usgs.gov/website/seamless/viewer.htm
	National Elevation Dataset 30 Meter	USGS	grid	30 m	http://seamless.usgs.gov/website/seamless/viewer.htm
	Shuttle Radar Topography Mission (SRTM) 30 Meter	NASA/USGS	grid	30 m	http://seamless.usgs.gov/website/seamless/viewer.htm
Ecoregions	Bailey Domains, Divisions, Provinces, and Sections	USDA Forest Service	polygon		http://www.fs.fed.us/rm/analytics/publications/eco_download.html
	Omernik Level 3 and Level 4	USEPA	polygon		http://www.epa.gov/wed/pages/ecoregions.htm
Geology	Major Bedrock Lithologic Units for Pacific Northwest	USGS	polygon	1:500,000	http://www.fsl.orst.edu/pnwer/wrb/access.html
	Geologic Map of Oregon including faults	USGS	polygon	1:500,000	http://www.oregon.gov/DAS/EISPD/GEO/alphalist.shtml
Hydrology	NHD Plus	USEPA/USGS	polygon, line, point, grids	1:100,000/30 m	http://horizon-systems.com/NHDPlus/index.php
	Rivers and Streams	Pacific Northwest Hydrography Framework	vector	1:24,000	http://www.oregon.gov/DAS/EISPD/GEO/alphalist.shtml
	Waterbodies	Pacific Northwest Hydrography Framework	vector	1:24,000	http://www.oregon.gov/DAS/EISPD/GEO/alphalist.shtml
	Hydrologic Units - 1st	Oregon BLM-USFS	polygon	1:24,000	http://www.oregon.gov/DAS/EISPD/GEO/alphalist.shtml

	through 6th Field				
	8-Digit Hydrologic Units (HUC)	USGS	polygon	1:250,000	http://water.usgs.gov/GIS/metadata/usgswrd/XML/huc250k.xml
	12-Digit Watershed Boundary Dataset		polygon	1:24,000	
	Willamette River Active Channel Timesteps (1850, 1895, 1932, 1995)	Oregon State University - Stan Gregory	polygon		http://www.fsl.orst.edu/pnwer/wrb/access.html
	1996 Willamette River Flood	unknown	polygon		http://www.fsl.orst.edu/pnwer/wrb/access.html
	1999 Willamette River Revetments between Eugene and Portland	Oregon State University/Dept. of Fisheries Wildlife - Linda Ashkenas	vector	1:24,000	http://www.fsl.orst.edu/pnwer/wrb/access.html
	Dams		point	1:24,000	http://www.oregon.gov/DAS/EISPD/GEO/alphalist.shtml
Soil	STATSGO Soils	NRCS	polygon	1:250,000	http://soils.usda.gov/survey/geography/statsgo/
	SSURGO Soils	NRCS	polygon	1:24,000	http://soils.usda.gov/survey/geography/ssurgo/index.html
	National Coordinated Common Resource Area (CRA)	USDA/Natural Resources Conservation Service	polygon	1:250,000	http://soils.usda.gov/survey/geography/cra.html http://datagateway.nrcs.usda.gov/
	WED field data (very small portion of WRB in forests)				
BIOLOGICAL					
Landcover	1851 Veg	Derived from surveys by the General Land Office			http://www.fsl.orst.edu/pnwer/wrb/access.html
	1938 Vegetation	Oregon Natural Heritage Program	polygon	1:100,000	http://www.oregon.gov/DAS/EISPD/GEO/alphalist.shtml
	NLCD 1992	Multi-Resolution Land Characteristics Consortium (MRLC)	grid	30 m	http://seamless.usgs.gov/website/seamless/viewer.htm
	NLCD 2001	Multi-Resolution Land Characteristics Consortium (MRLC)	grid	30 m	http://seamless.usgs.gov/website/seamless/viewer.htm
	Imperviousness 2001	Multi-Resolution Land Characteristics Consortium (MRLC)	grid	30 m	http://seamless.usgs.gov/website/seamless/viewer.htm
	GAP (1999)	Oregon Gap Analysis Program	polygon	1:100,000	http://www.oregon.gov/DAS/EISPD/GEO/alphalist.shtml
	GAP (2004)				

	Coastal Change Analysis Program (C-CAP) 1996	NOAA	grid	30 m	http://www.csc.noaa.gov/crs/lca/ccap.html
	Coastal Change Analysis Program (C-CAP) 2001	NOAA	grid	30 m	http://www.csc.noaa.gov/crs/lca/ccap.html
	Willamette Valley Land Use / Land Cover (1993)	Oregon Dept. of Fish and Wildlife	polygon	1:24,000	http://www.nwhi.org/index/gisdata
	Landuse and Landcover ca. 1990 - Willamette River Basin	University of Oregon, Institute for a Sustainable Environment	grid	25 m	http://www.fsl.orst.edu/pnwer/wrb/access.html
	Landuse and Landcover ca. 2000 - Valley Ecoregion of the Willamette River Basin	University of Oregon, Institute for a Sustainable Environment	grid		http://www.fsl.orst.edu/pnwer/wrb/access.html
	Landfire: Existing Vegetation Type	USDA Forest Service	grid	30 m	http://www.landfire.gov/
Forest	Pacific States Forest Vegetation Mapping	Gradient Nearest Neighbor (GNN) Pacific States	grid	30 m	http://www.fsl.orst.edu/lemma/gnnpac/spatialDatabases.php
	Tree Canopy Cover 2001	National Land Cover Dataset	grid	30 m	http://seamless.usgs.gov/website/seamless/viewer.htm
	National Biomass and Carbon Dataset 2000	Woods Hole Research Center	grid	30 m	http://www.whrc.org/nbcd/
Wetlands	National Wetlands Inventory	US Fish and Wildlife	polygon	1:24,000	http://wetlandsfws.er.usgs.gov/NWI/
	Willamette Valley Natural Wetlands	Oregon Natural Heritage Program	polygon		http://www.oregon.gov/DAS/EISPD/GEO/alphalist.shtml
IMAGERY	Digital Raster Graphics	USGS			http://seamless.usgs.gov/website/seamless/viewer.htm
	Digital Orthophoto Quadrangles	USGS			http://seamless.usgs.gov/website/seamless/viewer.htm
	National Agriculture Imagery Program (NAIP)	USDA			http://seamless.usgs.gov/website/seamless/viewer.htm
	Landsat 7 ETM+	USGS			http://glovis.usgs.gov
FUTURE SCENARIOS	Plan Trend 2000 - 2050: 10 year increments	Pacific Northwest Ecosystem Research Consortium	grid	30 m	http://www.fsl.orst.edu/lemma/gnnpac/spatialDatabases.php

Development 2000 - 2050: 10 year increments	Pacific Northwest Ecosystem Research Consortium	grid	30 m	http://www.fsl.orst.edu/lemma/gnnpac/spatialDatabases.php
Conservation 2000 - 2050: 10 year increments	Pacific Northwest Ecosystem Research Consortium	grid	30 m	http://www.fsl.orst.edu/lemma/gnnpac/spatialDatabases.php
Conservation Restoration Opportunities 2000 - 2050: 10 year increments	Pacific Northwest Ecosystem Research Consortium	grid	30 m	http://www.fsl.orst.edu/lemma/gnnpac/spatialDatabases.php

Appendix 2 Table 2: Listing of GEOSPATIAL SOPs that may be used in the Spatial Analysis tasks.

SOP TITLE	SOURCE & SOURCE SOP NUMBER	KNOWN AUTHOR(S) OR STEWARD(S)	GQC SOP NUMBER
GENERAL - PLANNING, MANAGEMENT, DISTRIBUTION OF DATA AND PRODUCTS, ETC.			
Development of Geo-SOPs	EPIC-2006-01c	Slonecker, Garofalo	GQC-SOP-001
Project Management	EPIC-2006-01a	Slonecker, Garofalo	GQC-SOP-003
Transfer of Spatial Data	AMD-APMB-004	William G. Benjey	GQC-SOP-005
GIS Map Display Development Standards	ERD-EAB023	Sandra Bird Lourdes Prieto	GQC-SOP-006
DATA ACQUISITION/COLLECTION/INPUT/PRE-PROCESSING			
GPS Data Collection	Region 5	Noel Kohl	GQC-SOP-008A
GPS Data Collection2	ERD-EAB048	Linda Exum	GQC-SOP-008B
GIS Data Entry	ERD-EAB019	Sandra Bird Lourdes Prieto	GQC-SOP-012
ANALYSIS/MODELING/PROGRAMMING			
Avenue Programming Development Standards	ERD-EAB016	Sandra Bird Lourdes Prieto	GQC-SOP-016
Avenue Custom Control Development Standards	ERD-EAB015	Sandra Bird Lourdes Prieto	GQC-SOP-017
ArcView 3-x Project File Management Development Standards	ERD-EAB014	Sandra Bird Lourdes Prieto	GQC-SOP-018
ArcView 3-x Extension Development Standards	ERD-EAB013	Sandra Bird Lourdes Prieto	GQC-SOP-019
Arc Macro Language Program Development Standards	ERD-EAB012	Sandra Bird Lourdes Prieto	GQC-SOP-020
Set-up of ArcGIS Mapping Environment	ERD-EAB047	Linda Exum	GQC-SOP-022
GIS Data Conversion Processing and Database Management	ERD-EAB018	Sandra Bird Lourdes Prieto	GQC-SOP-023
DATA QA/QC/METADATA - FINAL STEPS BEFORE DISTRIBUTION			
GIS Shapefile QC	ERD-EAB024	Sandra Bird Lourdes Prieto	GQC-SOP-024
GIS Image QC	ERD-EAB022	Sandra Bird Lourdes Prieto	GQC-SOP-025
GIS Grid QC	ERD-EAB021	Sandra Bird Lourdes Prieto	GQC-SOP-026
ACRONYMS			
EPIC	Environmental Photographic Information Center		
AMD	Atmospheric Modeling Division		
MEARB	Model Evaluation and Applications Research Branch		
APMB	Air-Surface Processes Modeling Branch		
ERD	Ecosystems Research Division		
EAB	Ecosystems Assessment Branch		
HEASD	Human Exposure & Atmospheric Sciences Division		
EMAB	Exposure Measurement & Analysis Branch		
R	Region		

Appendix 3. Collecting Primary Data

Date: October 1, 2010

Responsible COFFEE PI: Signature indicates Appendix is current as of the above date and will be implemented in conducting the research of this project.

Christian Andersen


Signature

10-25-10
Date

Project Leader: Signature indicates commitment to follow the procedures in this QAPP.

Paul Rygiewicz
Project Leader


Signature

10/25/10
Date

Quality Assurance: Signature indicates that this Appendix meets the quality requirements of WED.

Bob Ozretich


Signature

10/26/10
Date

Quality Assurance Manager

App3: Collecting Primary Data

The COFFEE project consists of several overlapping activities that will include primary data collection. Although data collection among the various tasks within COFFEE will be done in a complimentary way, each task represents a stand-alone effort and as such, will require stand-alone QC to insure reproducibility, accuracy and precision. Tasks 2.1, 2.2, 3, 4, 5 and 6.1 all involve collecting primary data. For routine data collection and supporting activities, all tasks will follow SOP TERA EP.00 dealing with general lab equipment (Balances, Calipers, pH meters, etc.) and TERA EP.04 dealing with rounding off and significant figure rules. Field site SOPs EP 17 and EEB/RW/2010-01 dealing with field site descriptions and LTEM Sites, respectively, will be followed for all field activities. The QA approach for each task is listed below, and the SOP Table (Appendix 3 Table 1) is attached at the end of the appendix.

App3: TASK 2.1 COF Scoring Metrics (Johnson)

The ultimate goal of Task 2.1 is to develop a map of current-climate $pTEC_{max}$ for the coniferous forested areas of the WRB. As described in the research plan, Homann et al. (2005) developed a relationship between soil organic C (SOC) in the top 20 cm of mineral soil (< 2 mm fraction) and TEC at present in a limited number of old-growth forest stands to predict current-climate $pTEC_{max}$. It is the general consensus of the COFFEE scientific staff that the robustness of this relationship should be more widely tested before it can be fully accepted and implemented and used to develop map of current-climate $pTEC_{max}$. The empirical part of Task 2.1 resides in subtask Task 2.1.1 (Evaluate the Assumptions of Homann et al. (2005) to Calculate TEC at Present and *Current-Climate* $pTEC_{max}$) and includes the following elements: 1) locating the population of old-growth coniferous forest stands in the WRB; 2) selecting representative stands from across the WRB; 3) identify a minimum of 3 plots within each stand; 4) quantify the amount TEC in each plot; 5) in each plot, sample and measure the soil properties used by Homann et al. (2005); 6) concurrently collect extra samples and make additional measurements in addition to those made by Homann et al. (2005) to potentially identify a more sensitive indicator(s) of current-climate $pTEC_{max}$; and 7) analyze the results. Each element is addressed below.

App3.2.1.B1 Experimental Design- The experimental design of this task will be formulated in consultation with other COFFEE members to ensure comparability of results and optimize crucial resources. Site selection will be based both on individual needs of the PI for the question they are addressing, and on the sites being used by other COFFEE members. Power tests will be run to identify sample frequency and required replication when estimates of variability are available. In some cases, instrument sensitivity and ease of use will determine the sample numbers that are feasible.

1) locating the population of old-growth coniferous forest stands in the WRB

This task (2.1.1) depends upon locating coniferous old-growth stands within the WRB. This will be accomplished through literature searches, professional contacts, contacting state, federal and private forest managers and possibly by conducting an inventory using recent aerial photography. To meet our needs, only stands that are 3 acres or greater will be included in the population. This provides a sufficient area for locating several plots from which forest data and soil samples will be collected.

2) selecting representative stands from across the WRB

Once the stands have been delineated, a subset of 30 stands will be selected. The goal is to have a set of representative stands from across the WRB. Consequently, selection of stands should not be purely random. Instead, a stratified random procedure will be used. Strata will be developed that group stands by location (e.g., Cascade Mountains, Coast Range Mountains), species, age, elevation, location in WRB (e.g., North vs. South), etc. Within each strata, each stand will be assigned a random number and the stand ranked by random number in ascending order. With the goal of 30 stands, if there are 6 strata for example, then 5 stands (i.e., the 5 with the lowest random number) from within each strata for inclusion in the study. Once identified owners will be located and permission requested to proceed with measuring TEC and collecting soil samples. Should permission be denied, then that stand will be removed and the next stand on the list added and so forth and so on until the target of 30 old-growth stands is achieved.

3) identify a minimum of 3 plots within each stand

Within each old-growth stand 3 plots will be identified for quantifying TEC and for collecting the soil-based samples. A plot will be defined as a circle that has a 16.05 meter radius. This defines a plot that is approximately one-fifth of an acre in size. Using GIS tools, each stand polygon will be filled with circles with 16.05 meter radii. Each circle will be assigned random numbers. Again, the candidate plots will be ranked according to their random number and the three with the smallest random numbers will be the plots used in this study. For some reason a plot need to be removed the next plot on the list will be selected instead and so forth and so on until 3 viable plots are identified.

App3.2.1.B2 Sampling Methods Requirements- This will vary depending on the instruments being used, and the sample to sample variability.

4) quantify the amount TEC in each plot

TEC of each one-fifth acre plot will be measured following the methods described in Smithwick et al. (2002), as used by Homann et al. (2005) or similar methods employed by the USDA Forest Service in their National Forest Inventory and Analysis (FIA) program (<http://fia.fs.fed.us/tools-data/>) or by the DOI Bureau of Land Management (BLM) (as used in the Panther Creek study and documented in an internal BLM document). The goal is to estimate above- and belowground plant carbon, including understory vegetation and downed woody debris. The reporting units will be in Mg C per ha.

5) in each plot, sample and measure the soil properties used by Homann et al. (2005)

Homann et al. (2005) utilized full soil profiles and measured forest floor carbon as well as soil carbon in three mineral soil depth increments and two size fractions (i.e., 0 – 20 cm, 20 – 50 cm and 50 – 100 cm; \leq or > 2 mm). However, the best relationship between TEC and soil organic carbon (SOC) was with total SOC in ≤ 2 mm size fraction from the 0 – 20 cm increment. For our validation of the Homann et al. (2005) method we will sample the forest floor and < 2 mm fraction of the 0 – 20 cm mineral soil increment only. This simplifies the level of effort required to collect these samples and allows for replicate samples to be collected in each forest plot. The soil samples will be collected so that soil bulk density and coarse fragments can be measured, which are needed to calculate the stock of SOC. These methods are described in the WED SOP entitled “Collecting and Processing Soil and Fine Tree Root Samples”, and in a new SOP that is being written on soil bulk density. These methods will use cores similar to Homann et al. (2005).

In the final analysis for Task 2.1.1 soil-based parameters will be regressed against TEC to determine the validity of the Homann et al. (2005) assumption to the WRB. Therefore, reliable estimates of both TEC and SOC are needed. Estimates of forest stand-level TEC will be derived from TEC measured on 3 plots within each stand. This follows the study design from the Panther Creek Watershed project [(Flewelling and Marshall, 2009: located at [\\AA.AD.EPA.GOV\ORD\COR\Data\Apps\QA\QAPdata\PROJECTS\\(\(EEB\) Ecological Effects Branch\Willamette Ecosystem Services\Panther Creek Study design.doc\)](\\AA.AD.EPA.GOV\ORD\COR\Data\Apps\QA\QAPdata\PROJECTS\((EEB) Ecological Effects Branch\Willamette Ecosystem Services\Panther Creek Study design.doc))]. Concomitantly, we plan to collect 4 forest floor and 4 co-located mineral soil samples from each forest plot. These will be randomly located within each plot as described below.

Each forested plot will be marked with a PVC pipe at the plot center. A list of randomly selected azimuths and randomly selected distances from the plot center will be used to locate the forest floor/mineral soil sample collection locations at each plot. Beginning at the plot center the person collecting the forest floor and soil samples will proceed on the azimuth the distance selected. If the point is acceptable for sampling (i.e., not a skid-road, pit, tree, stump, downed log, etc.) then it will be sampled. Should it not be acceptable, then the next pair of random azimuth and distance shall be used. This procedure will be followed until the 4 samples are successfully collected within each plot.

App3.2.1.B3 Sample Handling and Custody- An inventory of all soil samples (forest floor and mineral soil) will be kept beginning in the field. This inventory will be maintained throughout this study and will track the samples through the processing and analysis steps. All soil samples will be returned to WED where they will be refrigerated until the processing begins. Soils will be oven-dried at 60 °C and then sieved and processed as described in Homann et al. (2005) and the WED SOP entitled “Collecting and Processing Soil and Fine Tree Root Samples”. The soil samples will be considered stable after they are oven-dried and may be archived in a dry, temperature controlled room.

App3.2.1.B4 Analytical Methods- Any analytical methods employed with require the development of an SOP, which will be submitted for QA/QC approval.

The soil samples collected for this aspect of the COFFEE project will be processed as described in Homann et al. (2005) and analyzed for total carbon using TERA/GPEP 3.01 (Carbon/Nitrogen Elemental Analysis).

6) concurrently collect extra samples and make additional measurements in addition to those made by Homann et al. (2005) to potentially identify a more sensitive indicator(s) of current-climate $pTEC_{max}$

As described in the research plan, soil parameters other than those used by Homann et al. (2005) may be more strongly tied to TEC and provide more sensitive indicators of $pTEC_{max}$. For now the additional measures will include: active SOC (NRCS method and new WED SOP), particulate SOC (light SOC fraction < 1.8 gcm⁻¹ as described in GPEP SOP 2.0:Physical fractionation procedure to determine soil organic matter quality, density fractions (GPEP SOP 2.0:Physical fractionation procedure to determine soil organic matter quality), and a slight modification on these as described in Swanston et al. (2005) that also measure an occluded light fraction SOC and a free light (these represent labile and very labile forms of SOC, respectively), measures of pyrophosphate extractable

Fe and Al (a measure of SOC complexed with Fe and Al; common in acidic forested soils) (a new WED SOP to be written on determination of Al and Fe in pyrophosphate extracts of soil), and oxalate extractable Fe, Al and Si (a measure of potential SOC interactions with mineral surfaces having short-range order) (WED SOP EEB/MJ/2008-02: Determination of Oxalate Extractable Fe, Al, Si, Mn and P from Soils), and dithionite extractable Fe and Si (a measure of potential SOC interactions with layer silicate minerals) (WED SOP EEB/MJ/2008-01: Determination of Dithionite-Citrate Extractable Fe, Al and Mn from Soils). While the final list of these additional measures may be amended as this is a rapidly developing area of active research.

App3.2.1.B5 Quality Control- Data quality objectives (DQOs) will vary depending on the hypothesis being tested, and the needs that result from data sharing. DQOs including accuracy and precision will be specified in SOPs developed for each analytical procedure and instrument.

App3.2.1.B6 Instrument testing, Inspection and Maintenance-

As described in relevant SOPs.

App3.2.1.B7 Instrument Calibration-

As described in relevant SOPs.

App3.2.1.B8 Inspection/Acceptance Requirements for Supplies and Consumables-

As needed for relevant methods and procedures.

App3.2.1.B9 Data Acquisition Requirements- In most cases, data will be collected in an electronic format using software supplied for each instrument. After returning from the field, data will be backed up onto a PC before erasing the instrument databank. Office PCs are backed up daily. For handwritten data collection, standardized data forms will be printed *a priori* and filled out in the field using waterproof ink. Standard methods will be used for standard measuring devices.

App3.2.1.B10 Data Management- In general, all data will be stored electronically with paper primary data being stored in laboratory notebooks for documentation purposes. The electronic data will be stored in the COFFEE Task 2 folder – L:\Priv\CORFiles\Projects\COFFEE\A_Task2\Task2.1. Digital photos and all electronic media pertaining to this task will be stored here. These data files are backed up daily.

7) analyze the results

This part of the Task 2.1.1 relies upon regression analysis of the data gathered as a part of the task. The analysis will basically follow that described in Homann et al. (2005) in which measures of SOC (in Mg C ha⁻¹) are regressed against TEC (also in Mg C ha⁻¹). Strong relationships between the two variables will indicate that the assumptions of Homann et al. (2005) are valid for the WRB and will signal that measures of forest floor or mineral SOC can be used for scaling of pTEC_{max} across the WRB.

**App3: TASK 2.2 Assessing Trajectories of TEC with Regard to GCC and COF Practices-
(Beedlow and Waschmann)**

App3.2.2.B1 Experimental Design The experimental design will be formulated in consultation with other COFFEE members to ensure comparability of results and optimize crucial resources. Time series analyses will be used to determine the influence of climate factors on tree growth at the LTEM sites. For the forest management effects we will be selecting sites that have been subjected to various thinning and silvicultural practices, and then we will use tree cores in conjunction with historical met data to identify the influence of climate vs. management on tree growth. Site selection will be based both on individual needs of the PI for the question they are addressing, and on the sites being used by other COFFEE members. Power tests will be run to identify sample frequency and required replication when estimates of variability are available. In some cases, instrument sensitivity and ease of use will determine the sample numbers that are feasible.

App3.2.2.B2 Sampling Methods Requirements- This will vary depending on the instruments being used, and the sample to sample variability.

Long-Term Ecological Monitoring (LTEM) = EP17

Stem Flow Gauges = SOP GPEP 1.04. SOP GPEP 1.04 will need to be modified to reflect the type of sap flow sensors we will use. This will be completed by the end of calendar year 2010.

Automated Band Dendrometry = EEB/RW/2011-01. SOP EEB/RW/2011-01 will be completed by September 2011.

App3.2.2.B3 Sample Handling and Custody-

LTEM – N/A

Stem Flow Gauges = N/A

App3.2.2.B4 Analytical Methods- Any analytical methods employed with require the development of an SOP, which will be submitted for QA/QC approval.

LTEM – N/A

Stem Flow Gauges = N/A

App3.2.2.B5 Quality Control- Data quality objectives (DQOs) will vary depending on the hypothesis being tested, and the needs that result from data sharing. DQOs including accuracy and precision will be specified in Sop's developed for each analytical procedure and instrument.

LTEM – EP17

Stem Flow Gauges = SOP GPEP 1.04. SOP GPEP 1.04 will need to be modified to reflect the type of sap flow sensors we will use. This will be completed by the end of calendar year 2010.

App3.2.2.B6 Instrument testing, Inspection and Maintenance-

LTEM – EP17

Stem Flow Gauges = SOP GPEP 1.04. SOP GPEP 1.04 will need to be modified to reflect the type of sap flow sensors we will use. This will be completed by the end of calendar year 2010.

App3.2.2.B7 Instrument Calibration-

LTEM – EP17

Stem Flow Gauges = SOP GPEP 1.04. SOP GPEP 1.04 will need to be modified to reflect the type of sap flow sensors we will use. This will be completed by the end of calendar year 2010.

App3.2.2.B8 Inspection/Acceptance Requirements for Supplies and Consumables-

LTEM – N/A

Stem Flow Gauges = N/A

App3.2.2.B9 Data Acquisition Requirements- In most cases, data will be collected in an electronic format using software supplied for each instrument. After returning from the field, data will be backed up onto a PC before erasing the instrument databank. Office PCs are backed up daily. For handwritten data collection, standardized data forms will be printed a priori and filled out in the field using waterproof ink. Standard methods will be used for standard measuring devices.

LTEM – EP17

Stem Flow Gauges = SOP GPEP 1.04. SOP GPEP 1.04 will need to be modified to reflect the type of sap flow sensors we will use. This will be completed by the end of calendar year 2010.

App3.2.2.B10 Data Management- Data files maintained on WED server. Backed up to dedicated external hard drive annually and stored in a fireproof safe located in MB255 [P.A. Beedlow]

App3: TASK 3 Effects of COF and GCC on Biological Greenhouse Gas Regulation (BGHGR) (Andersen, Maynard)

App3.3.B1 Experimental Design- The overall goal of Task 3 is to improve our understanding of how different COF practices and GCC scenarios will impact forest ecosystem C and N processes and pools, and how these resulting impacts will affect BGHGR. The empirical component of this task has two specific objectives: 1) examine the effects of COF and GCC on forest soil C and N processes and pools, and 2) examine how these effects impact GHG (e.g., N₂O, CH₄, CO₂) flux.

The experimental design for objective 1 (i.e., examining COF and GCC effects on soil C) will contain both field and laboratory experiments. Laboratory experiments will be conducted to gain a more robust mechanistic understanding of the relationship between soil environmental conditions (i.e., soil moisture, soil temperature, and soil redox) and soil C dynamics. Specifically, these experiments will examine how changes in soil temperature and moisture influence soil redox conditions at the micro-scale and how these changes will affect soil C stability. To accomplish this, redox micro-gradients within isotopically labeled (^{13}C enriched ponderosa pine needles [*Pinus ponderosa* Laws.] will be mixed with forest A horizon soil) soil microcosms (see SOP- Soil microcosm construction and operation) will be quantified using microelectrodes (see SOP- Soil microelectrode analysis), allowing for the delineation of oxic, suboxic and anoxic zones. Soils will be incubated for 6 and 12 months at three moisture levels (air dry, field capacity [-.3 bar], and saturated [0 bar]) and two temperatures scenarios (current climate [12.5 °C] and future climate [17.5 °C]). To elucidate the effects of metal redox cycling on the transformation and stability of soil organic matter within each redox zone (i.e., oxic, suboxic, and anoxic), this study will integrate elemental (i.e., XRF, XAS) and molecular (i.e., μ -FTIR) imaging techniques. Synchrotron-based XRF, XAS, and μ -FTIR, conducted at Lawrence Berkeley National Laboratory (LBNL) (IAG “Investigating physical and chemical stabilization mechanisms affecting the longevity of soil organic carbon in forest ecosystems”, draft being written), will be used to characterize the distribution and speciation of redox metals, as well as provide information on the type of C functional groups associated with these metals in each redox zone. Following the completion of the synchrotron analyses, soil will be sampled from each redox zone, subjected to an alkaline cupric oxide (CuO) oxidation (Goni and Montgomery, 2000) (see SOP- Alkaline CuO digestion) to isolate lignin monomers from bulk soil organic matter (SOM), and analyzed using compound specific isotope analysis (CSIA). CSIA analysis will occur at Oregon State University’s Stable Isotope Research Unit (OSU-SIRU), a fee-for-service testing lab, following their QA/QC protocols. Lignin has long been regarded as one of the most stable biomolecules of SOM, and will thus be used as a conservative indicator of the effects of redox condition on SOM degradation (Heim and Schmidt, 2007; Hofmann et al., 2009). Through detecting changes in the original $\delta^{13}\text{C}$ signal, differences in the degree of lignin degradation between redox zones will be characterized. The number of replicate microcosm for each sample treatment will be determined, in consultation with LBNL scientists, based upon a number of samples that can be feasibly analyzed using synchrotron methods.

Field experiments for objective 1 will be conducted to assess the effects of forest management practices on micro-climatic and soil-climatic parameters and its subsequent impact on soil C stability. Utilizing sites along EPA’s LTEM transect, this work will examine relationships between soil C quality, soil temperature and moisture, and redox condition for a range of contrasting forest management practices. Specifically, this subtask will install soil redox sensors at four of EPA’s LTEM transect sites (Cascade Head, Falls Creek, Toad Road, and Soapgrass) where existing soil moisture and temperature sensors exist. This will allow us to characterize the relationship between soil temperature/moisture and soil redox condition. Utilizing a 20-year archive of soil samples from the Toad Road LTEM site, soil carbon quality will be characterized at paired clear-cut/mature forest sites using Fourier transform infrared spectroscopy (FTIR) (SOP in preparation) and thermogravimetry-differential scanning calorimetry (TG-DSC) (Plante et al., 2009). The clear-cut site was cut in 1991 and replanted in 1994. Soil samples were collected from the clear-cut site at 2, 3, 5, 7, and 19 years post-clear-cut and soil samples from the adjacent reference forested site were taken at

0, 9, and 19 years post-clear-cut. TG-DSC analysis will be conducted at the University of California, Davis (UC Davis) according to UC Davis standard protocol "STA 409 PC Luxx DTA/DSC SOP", which is being written at UC Davis and will be completed by 10/2010 (upon completion, Garrett Liles Department of Land, Air and Water Resources, University of California-Davis will supply WED with a copy of the SOP).

The experimental design of objective 2 will be formulated in consultation with other COFFEE members to ensure comparability of results and optimize crucial resources. Site selection will be based both on individual needs of the PI for the question they are addressing, and on the sites being used by other COFFEE members. Power tests will be run to identify sample frequency and required replication when estimates of variability are available. In some cases, instrument sensitivity and ease of use will determine the sample numbers that are feasible.

App3.3.B2 Sampling Methods Requirements- This will vary depending on the instruments being used, and the sample to sample variability. The SOP for the photoacoustic infrared gas analyzer (PAIGA) system is currently being developed for N₂O, CH₄, CO₂ and NH₄, but no physical samples will be collected for objective 2.

App3.3.B3 Sample Handling and Custody- The collection, transport, processing and storage of soil samples from EPA research sites will follow protocols outlined in SOP Tree Roots.

App3.3.B4 Analytical Methods- For analyses in objective 1 being run outside EPA, the standard Sop's developed by that institution for each instrument will be followed. Any new analytical methods employed will require the development of an SOP, which will be submitted for QA/QC approval. The following list of SOPs will be developed for this task:

- Soil microcosm construction and operation
- Soil microelectrode analysis
- Alkaline CuO digestion
- Field use of the photoacoustic infrared gas analyzer (PAIGA)

App3.3.B5 Quality Control- Data quality objectives (DQOs) will vary depending on the hypothesis being tested, and the needs that result from data sharing. DQOs including accuracy and precision will be specified in SOPs developed for each analytical procedure and instrument.

App3.3.B6 Instrument testing, Inspection and Maintenance- Will be outlined in the SOPs as they are unique for each piece of equipment.

App3.3.B7 Instrument Calibration- See SOPs

App3.3.B8 Inspection/Acceptance Requirements for Supplies and Consumables- Only reagent grade chemicals will be used in this task.

App3.3.B9 Data Acquisition Requirements- In most cases, data will be collected in an electronic format using software supplied for each instrument. After returning from the field, data will be backed up onto a PC before erasing the instrument databank. Office PCs are backed up daily. For handwritten data collection, standardized data forms will be printed *a priori* and filled out in the field

using pencil or waterproof ink. Three-ring binders will be used for storing original field forms chronologically. Standard methods will be used for standard measuring devices.

App3.3.B10 Data Management- All data from Task 3 will be stored in the Task 3 folder – L:\Priv\CORFiles\Projects\COFFEE\A_Task 3 Chris A et al. These data files are backed up daily.

App3: TASK 4 Effects of COF and GCC on Air Quality Regulation (Phillips)

App3.4.B1 Experimental Design- The overall objective of Task 4 is to assess the level of ecosystem services related to air quality provided by trees in areas within the Willamette River Basin. Models in the i-Tree software package will be used to assess the following relevant endpoints:

- tree VOC emissions (g m^{-2} canopy area yr^{-1} , metric tons yr^{-1})
- air pollutant removal quantities for O_3 , NO_2 , SO_2 , CO , and PM_{10} (g m^{-2} canopy area yr^{-1} , metric tons area yr^{-1})
- economic valuation of air pollutant removal ($\text{\$ yr}^{-1}$)
- energy savings due to shading of buildings (MWH or MBTU yr^{-1} , $\text{\$ value yr}^{-1}$)
- C storage in biomass (metric tons, $\text{\$ value in C markets}$)
- C sequestration rates (metric tons yr^{-1} , $\text{\$ value yr}^{-1}$ in C markets)

The only portion of Task 4 that will require primary data collection is associated with Task Outcome T4.2010 – *Application of i-Tree models to assess removal of air pollutants by trees within public lands in the Corvallis Urban Growth Boundary, and economic valuation of these benefits*. All other parts of Task 4 will use existing remote sensing and GIS data layers along with i-Tree models.

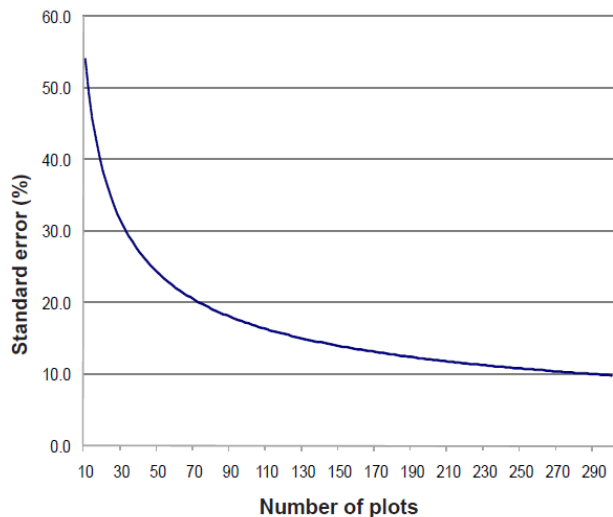
The assessments of public lands within the Corvallis UGB will be composed of three parts and will be analyzed in three separate i-Tree model runs. The first two will utilize only existing tree inventory data and will not require collection of new environmental data: (1) complete inventory of trees on the Oregon State University main campus; and (2) complete inventory of City of Corvallis maintained street trees within the UGB. Both of these data sets will be analyzed using the STRATUM model (now called i-Tree Streets). The third part is the only one that will require collection of new environmental data and involves measurement of all trees within approximately one hundred 0.1 acre plots randomly located within public lands in the Corvallis UGB. This data set will be analyzed using the i-Tree Eco model (formerly UFORE).

App3.4.B2 Sampling Methods Requirements- The i-Tree Eco User's Manual v. 3.1 (<http://www.itreetools.org/resources/manuals/i-Tree%20Eco%20Users%20Manual.pdf>) constitutes the SOP for data collection. The sample plots are to be 0.1 acre circular plots (37.2 ft radius) randomly located within all public lands in the Corvallis UGB. Measurements are to be made of general ground cover and all trees within the plots as specified in the User's Manual; no specific Shrub data are to be collected. Tree height measurement will follow SOP IO/PB/2003-04 Measuring Tree Height.

App3.4.B3 Sample Handling and Custody- Not applicable as there are no physical samples collected.

App3.4.B4 Analytical Methods- The i-Tree Eco model is the analytical method employed, as defined in the i-Tree Eco User's Manual v. 3.1 which constitutes the SOP for this method. Tree height measurement will follow SOP IO/PB/2003-04 Measuring Tree Height.

App3.4.B5 Quality Control- The Data Quality Objective (DQO) for the model estimates is a Standard Error of <20%. As shown by the figure below from the i-Tree Eco User's Manual, this can be achieved with approximately 72 sample plots randomly located throughout the study area of interest. One hundred sample plot locations are to be specified in order to achieve this DQO even if some of the plots are unable to be sampled due to physical inaccessibility or lack of permission.



Five percent of the sample plots are to be remeasured in order to assess precision. The DQOs for these remeasurements are shown in the table below (from i-Tree Eco User's Manual):

Variable	Measurement unit	MQO
Land use	Land use	No errors, 99% of the time
Plot tree cover	5% classes	Within two 5% classes, 95% of the time
Tree count		
< 25 trees on plot	Presence/absence	No errors, 90% of the time
≥ 25 trees on plot	Presence/absence	Within 3% of total, 99% of the time
Tree species (or genus if species cannot be determined)	Species	No errors, 95% of the time
DBH		
Tree with 1–10 inch DBH	0.1 inch	Within 0.1 inch, 95% of the time
Tree with > 10 inch DBH	0.1 inch	Within 3%, 95% of the time
Tree total height	1 ft	Within 10%, 95% of the time
Building interaction	No. of buildings	No errors, 95% of the time

App3.4.B6 Instrument testing, Inspection and Maintenance- The hand-held GPS unit used for locating sample plot locations in the field will be periodically tested using [SOP IO-BO-2010-01-r0 Accuracy of recreational GPS units.doc](#). Extra batteries will be carried into the field in case of the need for replacement.

App3.4.B7 Instrument Calibration- See [SOP IO-BO-2010-01-r0 Accuracy of recreational GPS units.doc](#).

App3.4.B8 Inspection /Acceptance Requirements for Supplies and Consumables- Not applicable.

App3.4.B9 Data Acquisition Requirements- Data will be entered in the field on paper forms provided in the i-Tree Eco User's Manual. The data will then be entered into Microsoft Access database files formatted for use with i-Tree Eco. (The User's Manual specifies how to set up a "project" and create the data files necessary.)

App3.4.B10 Data Management- The i-Tree Eco "project" files will be stored in the COFFEE Task 4 folder – L:\Priv\CORFiles\Projects\COFFEE\A_Task 4 Don P et al. Digital photographs of each sample location will also be stored here. These data files are backed up daily

App3: TASK 5 Effects of COF and GCC on Water Quantity and Quality Regulation (McKane)

There is a rich history of scientific studies in the PNW addressing effects of forest management on water quality and quantity, including long-term monitoring of stream discharge and chemistry for watersheds in the Cascade Range (e.g., "*Envision Andrews*" <http://envision.bioe.orst.edu/StudyAreas/Andrews/andrews.htm>) and Coast Range (e.g., Alsea Watershed Study, <http://www.ncasi.org/programs/areas/forestry/alsea/default.aspx>). Consequently, there is no need for new experimental work. Instead, this task will rely on data mining of existing scientific literature to obtain hydrologic data and ERFs that WESP requires for modeling effects of COF and climate on stream water quality and quantity. WESP already has assembled many of these water quality/quantity data sets, and incorporated and validated the ERFs for climate and land use into VELMA, a spatially-distributed eco-hydrologic model that simulates the integrated responses of multiple ecosystem services (regulation of water quality and quantity, C sequestration, GHGs, etc.) to interacting stressors. Details are provided in the WESP Implementation Plan and WESP QAPP.

App3. TASK 6.1 Predicting Changes in Habitat Structure (Rygiewicz, McKane)

App3.6.1.B1 Experimental Design- The long-term goal of the work in this sub-task is to test and apply statistically-based Stand Density Response Functions (SDRFs) to predict effects of COF, specifically stand density management, on spatial and temporal changes in forest habitat structure. By representing size- and density-dependent competition among individual trees for above- and belowground resources (light and CO₂, and nutrients and water, respectively), the SDRFs can be used to predict growth and mortality of individual trees during stand development. Thus, we will use the SDRFs to predict successional changes in 3-D structure and biomass distribution within forest habitats, including sizes and spatial distributions of live and dead snags by species, and C allocation

to leaves, stems and roots. Predictions will address COF effects on forest habitat structure from stand inception to old-growth.

Our first step will be to develop proof-of-concept SDRFs for old-growth forests on the western slopes of the Cascade Range (McKane et al. 2004a; McKane et al. 2003; McKane et al. 2004b). Work that is planned as of the date of this Appendix consists of taking new tree tissue samples to determine up-to-date retranslocation rates of previous stable isotope (¹⁵N) amendments, and analyzing these new samples and archived tissues samples according to an experimental design identified in the INFER and Terrestrial Habitats WED projects. The SDRFs we intend to develop describe the effects of competition among individual trees for belowground resources. Nitrogen is a key limiting resource in most forests in the Willamette Basin. Therefore, it is important to quantify the acquisition, allocation and retention of nitrogen within trees during stand development. The experimental ¹⁵N data describing these processes will inform the SDRFs we will develop for this project. The experimental design and methods for this work are described in SOP EEB/BM/2003-01, Section B, including field site description (B.1), experimental design (B.2), application of tracers (B.3), pre-labeling harvest of plant tissues (B.4), harvest of tracer-labeled plant tissues (B.5, B.6), field measures of bole and branch allometry (B.7), laboratory measures of branch allometry (B.8), calculation of whole-tree tissue biomass (B.9), and tissue sorting and analysis of tracer-labeled branch samples (B.10, B11). .

Once these samples are processed and the results evaluated, additional work at new locations in the WRB will be initiated. Before that work commences, the experimental design of the additional work will be formulated in consultation with other COFFEE members to ensure comparability of results and optimize crucial resources. Selection of new sites will be based on the needs of the primary PIs responsible for this sub-task to answer the more narrow questions they need to address, and on the needs of the larger project by locating new sites at locations that include those being used by other COFFEE members. Power tests will be run to identify sample frequency and required replication when estimates of variability are available, and will be aided by relying on the results to be obtained from the initial stage of work described above.

App3.6.1.B2 through A3.6.1.B10 - The QA elements of the procedures to be used in this sub-task are presented in SOPs (see Appendix 3 Table 1 for further details):

IO/PB/2003-01	Measuring Tree Crown Diameter, Beedlow
IO/PB/2003-02	Measuring Water Content of Wood Tissues, Beedlow
IO/PB/2003-03	Spatially Mapping Trees at Forested Sites, Beedlow
IO/PB/2003-04	Measuring Tree Height, Beedlow
IO/PB/2003-05	Mapping Field Sites, Beedlow
	Installation and Reading of Series 5 Manual Band Dendrometers,
IO/PB/2003-06	Beedlow
IO/PB/2003-07	Measuring Tree Diameters, Beedlow
	Tracer Methods for Quantifying Plant Nutrient Uptake and
EEB/BM/2003-01	Allocation, McKane
INFER SOP 5.1.3	Tree DNA Fingerprinting Above- and Belowground, Rygiewicz

Processing of samples and management of data for stable isotope analyses of tree tissues, once submitted to ISIRF, will follow approved QA/QC procedures of ISIRF.

References

- Goni, M.A., and S. Montgomery. 2000. Alkaline CuO oxidation with a microwave digestion system: Lignin analysis of geochemical samples. *Analytical Chemistry* 72:3116-3121.
- Hofmann, A., A. Heim, B.T. Christensen, A. Miltner, M. Gehre, and M.W.I. Schmidt. 2009. Lignin dynamics in two ¹³C-labelled arable soils during 18 years. *European Journal of Soil Science* 60:250-257.
- Heim, A., and M.W.I. Schmidt. 2007 Lignin turnover in arable soil and grassland analysed with two different labeling approaches. *European Journal of Soil Science* 58:599-608.
- McKane R, Rygiewicz P, Andersen C, Beedlow P, Brooks R (2004a) Functional overlap of root systems in an old-growth forest inferred from tracer ¹⁵N uptake. In: 4th International Conference on Applications of Stable Isotope Techniques to Ecological Studies, Wellington, New Zealand
- McKane R et al. (2003) Lateral root distribution of trees in an old-growth Douglas-fir forest inferred from uptake of tracer ¹⁵N. In: Ecological Society of America meeting. Ecological Society of America, Savannah, GA
- McKane R et al. (2004b) Above and belowground controls on forest tree growth, mortality and spatial pattern. In: Ecological Society of America meeting. Ecological Society of America, Portland, OR
- Plante, A.F., J.M. Fernandez, and J. Leinfeld. 2009. Application of thermal analysis techniques in soil science. *Geoderma* 153:1-10.

APPENDIX 3 Table 1: SOPs and External QA/QC References

Number	SOP/External Reference Title	Approval date / Biennial Review date
Task 2 - COF Scoring Metrics & Scaling to Landscapes – M Johnson		
IO/PB/2003-01	Measuring Tree Crown Diameter, Beedlow	5/14/07 / 8/25/10
IO/PB/2003-02	Measuring Water Content of Wood Tissues, Beedlow	5/14/07 / 8/25/10
IO/PB/2003-03	Spatially Mapping Trees at Forested Sites, Beedlow	5/14/07 / 8/25/10
IO/PB/2003-04	Measuring Tree Height, Beedlow	5/14/07 / 8/25/10
IO/PB/2003-05	Mapping Field Sites, Beedlow	5/14/07 / 8/25/10
	Installation and Reading of Series 5 Manual Band	
IO/PB/2003-06	Dendrometers, Beedlow	5/14/07 / 8/25/10
IO/PB/2003-07	Measuring Tree Diameters, Beedlow	5/14/07 / 8/25/10
GPEP 1.04	Stem Flow Gauge	6/9/97 / 12/2010
EEB/RW/2010-01	Automated Band Dendrometry	9/2011
	Determination of Oxalate Extractable Fe, Al, Si, Mn and	
EEB/MJ/2008-02	P from Soils, Johnson	1/23/2009
	Determination of Dithionite-Citrate Extractable Fe, Al	
EEB/MJ/2008-01	and Mn from Soils, Johnson	1/23/2009
EEB/JM/2011-01	FTIR Analysis, J. Maynard	1/2011
TERA/GPEP 3.01	Carbon/Nitrogen Elemental Analysis, Johnson	8/23/2010
	Collecting and Processing Soil and Fine Tree Root	
EEB/MJ/2004-01	Samples, Johnson	8/23/2010
EEB/MJ/2011-01	Soil Bulk Density, M. Johnson	1/2011
Task 3 - Effects of COF & GCC on Biological Greenhouse Gas Regulation – C Andersen		
	Measuring Trace Gas Fluxes from Field Soils Using the	
EEB/CA/2011-01	Photo Acoustic Infrared Gas Analyzer (PAIGA) System, Andersen	1//2011
	Soil Redox Probe Construction, Calibration, Installation,	
EEB/JM/2011-02	and Retrieval, J. Maynard	1/2011
EEB/JM/2011-03	Soil Microelectrode Analysis, J. Maynard	1/2011
Task 4 - Effects of COF & GCC on Air Quality Regulation – D Phillips		
	Determining the Accuracy of Recreational Grade GPS	
IO/BO/2010-01	Units, Phillips	6/24/2010
Task 6 - Effects of COF & GCC on Wildlife Pop. & Hab. Suitability – P Rygielwicz		
	Tracer Methods for Quantifying Plant Nutrient Uptake	
EEB/BM/2003-01	and Allocation, McKane	5/2/2003 / 7/20/2010
	Tree DNA Fingerprinting Above- and Belowground,	
INFER SOP 5.1.3	Rygielwicz	8/30/2010
Supporting Activities - P. Rygielwicz		
Field Sites		
	Forest Field Site Descriptions: Project FEP Number 17,	
LTEM EP 17	Version 1.00 , Beedlow/Waschmann	4/14/1998 / 8/24/2010
	Cascade Meteorological Station Operation and Data	
INFER FOP.01	Collection (Waschmann as of 2010)	4/29/1998 / 8/25/2010
Basic Lab Procedures & Data Manipulation		
	Procedures for General Lab Equipment (Balances,	
TERA EP.00 v3	Calipers, Leaf Area Meters, pH Meters), Johnson	2/28/2008 / 8/31/2010
TERA EP.04 v4	Rounding Off/Significant Figure Rules (General), EH Lee	3/28/2008 / 8/31/2010

Appendix 4. Modeling

Date: October 1, 2010

Responsible COFFEE PI: Signature indicates Appendix is current as of the above date and will be implemented in conducting the research of this project.

Paul Rygiewicz Paul Rygiewicz 10/25/10
Signature Date

Project Leader: Signature indicates commitment to follow the procedures in this QAPP.

Paul Rygiewicz Paul Rygiewicz 10/25/10
Project Leader Signature Date

Quality Assurance: Signature indicates that this Appendix meets the quality requirements of WED.

Bob Ozretich Robert Ozretich 10/26/10
Quality Assurance Manager Signature Date

App4: Modeling

COFFEE is reliant on WESP for the work done there in on developing and/or using models, developing the *ENVISION* decision support platform, and adhering to necessary related QA/QC requirements as described in the WESP Research Plan and the *QAPP for Willamette Ecosystem Services Project (WESP)* (Bolte 2010). Specifically, the Tasks and Activities described in Table 1 of the *QAPP for Willamette Ecosystem Services Project (WESP)* encompass the modeling work that will support the efforts done on COFFEE. COFFEE will rely the WESP PIs to comply with the QA/QC requirements described in the WESP QAPP, and that will be evidenced by the periodic audits conducted of WESP by the WED Quality Assurance Program.

Bolte J (2010) QAPP for Willamette Ecosystem Services Project (WESP). QAPP-NHEERL/WED/EEB/JB/2010. 21 pps.